# RESTORATION OF NEW CHICAGO MARSH: HYDROLOGIC AND WATER-QUALITY INFLUENCES AND PROPOSED OPERATIONS PLAN

Prepared for:

Peninsula Open Space Trust

By:

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With appendix by
William Nuttle

February 1990

A Report Prepared For:

Peninsula Open Space Trust
3000 Sand Hill Road, Bldg 4, Ste. 135
Menlo Park, CA 94025
Attention: Mr. John Wade

# RESTORATION OF NEW CHICAGO MARSH: HYDROLOGIC AND WATER-QUALITY INFLUENCES AND PROPOSED OPERATIONS PLAN

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Balance Hydrologics, Inc. Project 8822.2

8822.2

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Mr. John Wade
Peninsula Open Space Trust
3000 Sand Hill Road, Bldg. 4, Ste. 135
Menlo Park, CA 94025

Dear John:

Attached is a draft of our report on directions which the Peninsula Open Space Trust might pursue in managing the hydrology and water quality influences affecting restoration of New Chicago Marsh. You have previously received a biotic survey, baseline, and recommended program from Harvey & Stanley Associates.

A primary objective in restoration of this marsh is improvement of the soil and water regime to promote growth of pickleweed, Salicornia. We understand that broader and more luxuriant growth of the pickleweed will provide improved habitat for the salt marsh harvest mouse. POST will design and develop the restoration program; the U.S. Fish & Wildlife Service will operate the restored marsh.

We have surveyed possible sources of water for restoring this diked wetland. Of these sources, water entering through Triangle Marsh is likely to have salinity characteristics most appropriate to the needs of Salicornia. Nutrient levels at this source are high, and growth of algae or other aquatic organisms may be promoted using water from this source. Inflow of trace elements and heavy metals is expected to be small relative to the amount currently found in the biologically-active upper 6 inches of marsh sediments. Feasible alternate supplies contain higher levels of nutrients and trace elements, plus lower, less-appropriate salinities.

Marsh restoration is a challenging task, particularly in this setting, where ground subsidence precludes estuarine circulation. We have discussed several potential situations with you and with USFWS which may require active management of the marsh. It is our understanding that both you and USFWS remain enthused regarding the potential for restoring this very important wetland, and are prepared to manage, monitor, and revise the operating regimes in the years to come. Our report is presented in a manner intended to aid in assessing present conditions and the various contingent management options which will be available. Per our discussions, continuous real-time monitoring of salinity and water level within the marsh and at the Triangle Marsh intake one mile to the north will be needed to enable regular response to changing conditions, particularly during the initial years.

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The restoration plan has benefitted both from your direct, material contributions and from your review. Other reviewers have also offered significant suggestions and observations. We look forward to receiving and responding to further comments developed by readers and reviewers during the permitting process.

At your request, we are to begin developing detailed plans for the intake and outflow areas. These, the operations manual, and detailed cost estimates for the facilities are to be developed once you have approved the conceptual management program.

Please do not hesitate to contact us with any questions.

Sincerely,

BALANCE HYDROLOGICS, Inc.

Barry Hecht

Barry Hecht
Principal Hydrologist

cc: Dr. Bill Nuttle
Dr. Ben Roberts

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# 1 INTRODUCTION

This study addresses the feasibility of restoring diked wetlands in New Chicago Marsh and enhancing its habitat values. The proposed program involves circulating local waters into and out of the marsh. Water levels will be raised from approximately elevation -5.0 feet at present, to a stable level at -2.0 feet (NGVD). A primary goal of the restoration is to provide improved habitat for the endangered salt marsh harvest mouse.

New Chicago Marsh is located at the southern end of San Francisco Bay, immediately north and east of the community of Alviso. The location and hydrologic setting of the marsh are shown in Plates 1 and 2.

## 1.1 PREVIOUS WORK

This investigation follows several biological analyses of New Chicago Marsh by Harvey & Stanley Associates, culminating in a 1986 report summarizing the field studies (Harvey and others, 1986). The authors concluded that the endangered salt marsh harvest mouse is the species of primary concern. The mouse is present in New Chicago Marsh, notably in the western half; most of the parcel is considered suited as habitat, particularly if restored. Other small rodents utilizing the site are reported to include the California vole, western harvest mouse, Norway rat, house mouse, and deer mice. The habitat sought in New Chicago Marsh is an extensive cover of common perennial pickleweed, which is thought favorable for expanding populations of the salt marsh harvest mouse, given the distribution of other small rodents and the need for shelter from predation. Subsequent analyses by agency biologists have affirmed the need to maximize the distribution of pickleweed throughout the site, with the exception of a small area adjacent to the Environmental Educational Center, where a transitional gradient from freshwater through brackish water to salt water marsh may eventually be established without harming the salt marsh harvest mouse. The Harvey & Stanley Associates report recommended that a hydrologic and water quality investigation be conducted to assess whether these goals might be accomplished and how they may be best implemented.

The Harvey & Stanley report contains important descriptions of vegetation and wildlife at the site. Readers of this report are urged to consult the companion biological documents. They also include field measurements of salinity, pH, and other descriptors developed in the course of the biotic investigations. A number of samples of soils were also analyzed for major constituents (Appendix D, this report). We were asked to develop our assessment based on these observations. They were supplemented by additional measurements of water salinity by student volunteers (Appendix B, this report) and by the Environmental Education Center staff (Appendix C, this report). Previous investigation for an eventual restoration plan was conducted by a consultant to a major land developer, who chose not to make these results available for this public-entity study.

## 1.2 ORGANIZATION OF THIS REPORT

We report the results of the hydrological and water-quality investigations in six main sections of this report:

1) Introduction
2) Goals and objectives for design
3) Existing soil and hydrologic conditions
4) Specific design considerations
5) Proposed operating and monitoring programs
6) Conclusions

In light of the importance of expanding the area covered by Salicornia, we sought guidance from William Nuttle, a widely-acknowledged expert on the soil and water influences upon pickleweed development in salt marshes on the eastern and Gulf coasts. Dr. Nuttle's analysis of conditions at the site and his suggestions to us in recommending an operation plan are presented in Appendix A. Not all of the measures which he believes will enhance pickleweed distribution at this site can be implemented; however, many of his recommendations are incorporated in the suggested program.

Supplemental water and sediment quality observations made in 1986 and 1987 by student volunteers are presented in Appendix B. Debby Johnston made a number of field measurements in support of this investigation (Appendix C). We have also included the agronomic soils analyses developed earlier by Harvey & Stanley Associates (Appendix D) for context.

Unless otherwise stated, all elevations cited in this report are with respect to NGVD.

## 1.3 AUTHORIZATION

The Peninsula Open Space Trust (POST) will provide the funding and support to restore the marsh, and is charged with developing the conceptual plans, operating regimes, and monitoring programs. The San Francisco Bay National Wildlife Refuge, a unit of the U.S. Fish and Wildlife Service (USFWS), will manage the restored facility, and its staff provides direction during plan development.

POST initially arranged for a preliminary feasibility assessment of marsh restoration by biologists from Harvey and Stanley Associates. The biological report recommended that restoration be pursued using a steady water level. The HSA report also included broad-spectrum analyses of sediment and waters from within the marsh. These analyses exhausted the limited funds available for sampling and testing of soils and waters. The HSA also recommended that a hydrologic and water-quality assessment of the feasibility of marsh restoration be conducted.

Barry Hecht and Kurt Seel were originally asked to conduct the hydrology and water-quality assessment. The scope of work was gradually expanded to include the hydrography, hypsography, and then the operating plan for the marsh. Interim reports reflecting the broadening scope were prepared by the authors while they were employed by Kleinfelder (1987; 1988), which retained Dr. Nuttle as a consultant. Balance Hydrologics conducted the final stages of the assessment after both authors had resigned from the original contractor.

## 1.4 ACKNOWLEDGMENTS

John Wade of the Peninsula Open Space Trust (POST) has been the driving force behind the plan to restore New Chicago Marsh, and has coordinated the planning, design and acquisition efforts which underlie the restoration program. The staff of Balance Hydrologics are also appreciative of assistance and suggestions offered by the following individuals:

U.S. Fish and Wildlife Service
- Debby J. Johnston
- Rick Coleman
- Thomas E. Harvey
- Kevin Forrester
- Jean Takagawa

California Department of Fish and Game
- Armand G. Gonzales
- Carl Wilcox

California Regional Water Quality Control Board,
San Francisco Bay Region

- Richard Whitsell
- Michael Carlin

Harvey & Stanley Associates
- Dr. H. Thomas Harvey

Abaris/Hydro-Lift
- Roger Austin
- Jim Chase

# 2 GOALS AND OBJECTIVES FOR DESIGN

A number of various management goals have been identified for New Chicago Marsh over the years. Present general goals and objectives for marsh restoration are discussed in the following paragraphs, based on the stated intent of POST, and staff of the U.S. Fish and Wildlife Service (USFWS), San Francisco Bay National Wildlife Refuge.

## 2.1 PRIMARY GOALS AND OBJECTIVES

The primary long-term goal of the proposed restoration program is to enhance local habitat for the salt marsh harvest mouse. Among the criteria for achieving this goal are:

- Increasing the extent, density, and biomass of the local pickleweed, primarily *Salicornia pacifica*, the preferred habitat for the endangered mouse.
- Providing some degree of open-channel separation of pickleweed patches, to discourage the regular presence of unwanted predators, particularly feral dogs.
- Controlling water levels such that islands and other non-flooded areas are available throughout the marsh when water levels are at annual or seasonal maxima.

Encouraging more robust and extensive pickleweed is considered the most significant of these factors by the U.S. Fish and Wildlife Service and by the California Department of Fish and Game, the agencies with most immediate jurisdiction over salt marsh harvest mouse management.

## 2.2 SECONDARY GOALS AND OBJECTIVES

Secondary goals and objectives for the proposed restoration of the New Chicago Marsh include:

1. Restoring a salt-marsh type of habitat to a currently deteriorated and botanically impoverished area:

- Providing a substrate suited primarily for pickleweed, but with edge diversity allowing development of areas of salt grass, cord grass, and other brackish-water plants
- Gradually reducing soil salinities, which locally can be extreme, to levels similar to those found in most salt-water marshes throughout the South Bay, so that the growth of pickleweed and other plants may be sustained without excessive intervention
- Enhancing a local environmental amenity for the Alviso area, and for the South Bay in general
- Operating the marsh in a manner consistent with the goals and activities of the Environmental Education Center, which may eventually include providing a small area of fresh-water marsh and its transition to the salt-marsh environment and generally maximizing diversity near the Center
- Increasing waterfowl food sources and habitat, provided that this is consistent with the primary needs of the salt marsh harvest mouse
- Sustaining tidal channels which retain the appearance and certain functions of those found in adjoining natural systems retaining connection with the Bay.

2. Retaining upland transition areas surrounding and at the margins of the marsh.

3. Managing for a diversity of wildlife, provided that this does not conflict with salt marsh harvest mouse habitat.

4. Be able to operate in conformance with the City of San Jose's intended use of the marsh as a floodwater basin during extreme runoff events; under such conditions, maximum water levels reportedly are expected to be -1.0 feet (Nolte and Associates, 1983).

5. Minimizing vector-control problems associated with the restored wetland; criteria provided by the Mosquito Abatement District call for either minimal water-level fluctuations or very rapid fluctuations to preclude the breeding of larvae.

6. Providing basic, but essential, protection from upsets, spills, or short-term water quality events in Artesian Slough; if the slough will eventually supply a freshwater perennial wetland. Because water in Artesian Slough emanates primarily from the San Jose/Santa Clara Wastewater Treatment Plant, several hours of detention of waters introduced from the slough into the marsh should be incorporated in the intake design for the freshwater marsh to allow settling or volatilization. Anticipated constituents of concern are trace metals, residual chlorine, other substances which may sharply shift pH values, or floating volatile organic compounds.

## 2.3 OVERALL MANAGEMENT APPROACH

Both POST and the USFWS have informed us that they recognize that active management of the restored marsh will be necessary. The agencies are committed to special attention during the initial years of the restoration effort, as new biotic, soil-salinity, and water-quality regimes evolve. The two agencies recognize that the existing conditions are both unique and extreme. Additionally, soil and hydrologic conditions within the 340-acre marsh are understood to be highly variable. Hence, they have chosen to approach marsh restoration with a site-specific program involving:

1. Attempting to anticipate and design for control of the primary ecological limitations

2. Monitoring water, soil, and vegetation, with particular attention to the initial years of adjustment following hydrologic manipulation

3. Responding to deviations from expected or desired ranges.

This report has been prepared to assist in further refining this strategy.

# 3 EXISTING SOIL AND HYDROLOGIC CONDITIONS NEW CHICAGO MARSH AND VICINITY

Certain of the existing conditions affecting the planned restoration of New Chicago Marsh are described in this section of the report. Other pertinent materials of a biotic or regional water quality character are found in other, widely available sources such as the Harvey & Stanley Associates Study (Harvey and others, 1986), annual reports of the San Jose/Santa Clara Water Pollution Control Plant, and the yearly summaries of monitoring conducted on behalf of the South Bay Dischargers Authority (Walker and others, 1982; 1983; 1984; and 1985).

## 3.1 HYDROGRAPHY

New Chicago Marsh is a diked wetland, separated since the 1890's from estuarine channels marginal to San Francisco Bay. The marsh area is bounded on the east by Artesian/Mallard Slough; at the site, flow in Artesian/Mallard Slough is tidal, but consists overwhelmingly of treated effluent discharged from the San Jose/Santa Clara Water Pollution Control Facility. Salinities in Artesian/Mallard Slough typically range between 1 and 2 parts per thousand (ppt). Alviso Slough, another freshwater channel, is located to the west of the marsh, separated by a levee and railroad embankment. A solar evaporation pond, one in an integrated chain operated by the Leslie Salt Company, lies immediately north of the site; salinities in this pond vary, but a representative value may be 75 ppt (see Appendix C). The community of Alviso lies to the south, beyond a levee and railroad or roadway embankments. Portions of New Chicago Marsh are owned primarily by any one of four entities (San Francisco Bay National Wildlife Refuge, City of San Jose, Santa Clara County, Leslie Salt Corp.) as shown in Plate 3. There are also scattered private inholdings which POST is attempting to purchase.

The marsh surface is presently at elevations of -2 to -5 feet in most locations, a reflection of regional land subsidence induced by ground-water overdraft during the mid-1930's through late-1960's. Subsidence contours of the Santa Clara/Alviso area are presented on Plate 4. The present hydrography within most of the marsh includes tidal channels formed while the land was higher, and while still connected to San Francisco Bay and the adjoining sloughs. These relict features, however, are significant elements of the present marsh, providing drainage, limited aquatic habitat, isolation of pickleweed patches, and an aesthetic landscape appreciated and expected by many visitors.

The largest of the relict channels, known as Grey Goose Slough, is an important element in circulation within the marsh. Grey Goose Slough extends inland beneath the bounding levee and roadway, receiving drainage from a low-lying area to the southeast. This bottomland, bounded by Alviso-San Jose Road (west), Highway 237 (south), and low levees extending southward from the easternmost corner of the marsh, has had a contributing drainage area to the marsh of approximately 275 acres. This area is presently used primarily for agriculture (about 70 acres), grazing (about 130 acres), and freshwater wetlands (about 40 acres); approximately 35 acres presently are vacant. The contributing watershed is likely to be reduced by about 105 acres over the next few years as the farmed and vacant land is developed into an industrial park. Initial grading and construction for this facility is already underway. It is thought that runoff from the park will be conveyed to the Guadalupe River through existing regional storm drains. The balance of the area is mostly owned by the City of San Jose as a buffer surrounding the sewage treatment plant. Approximately 40 acres are used a a fill site by Owens Corning, which operates a fiberglass manufacturing facility several miles to the south. Owens Corning owns approximately 25 acres of degraded salt marsh south of Grand Avenue which serve as a buffer between the landfill and the southern boundary of New Chicago Marsh.

If this watershed has been managed in a manner similar to other lands adjoining San Francisco Bay, the water-quality runoff from past land uses within this contributing area probably has not substantially affected the marsh soils. No soil analyses for toxic constituents have been conducted within the marsh; the heterogeneity of past influences and existing conditions suggests that isolated samplings would probably be of limited use for marsh planning. A hydrologic assessment report (HAR) for the Owens-Corning landfill is under way and may provide additional insights into past water quality patterns.*

Freshwater inflows during storms and perhaps at other times of year may continue to be contributed from the remaining 170 acres (more or less) draining to Grey Goose

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* The two preceding paragraphs have been modified from a memo prepared by John Wade, project manager for POST.

Slough, unless this runoff is redirected, perhaps by blocking the culvert beneath Grand Avenue near the southeastern corner of the marsh.

### 3.2 HYPSOMETRIC ANALYSES

In order to calculate the volume of water necessary to regulate the water level within the marsh, hypsometric curves were calculated for both the surface area and volume of the marsh. These curves were calculated by subdividing the marsh into sectors, as shown on Plate 5, and using a planimeter to determine the surface area in each sector. Table 1 presents the total surface area of each subdivision between the elevations indicated. The surface area and volume hypsometric curves for New Chicago Marsh are presented on Plates 6 and 7, respectively. These data were used to approximate the volume of water necessary to regulate water levels in the marsh for different hydrologic scenarios.

### 3.3 EXISTING CONDITION OF MARSH VEGETATION

The primary species of vegetation within the marsh, and the primary target for vegetative enhancement, is the perennial pickleweed (Salicornia pacifica). Currently, most of the pickleweed within the marsh appears stressed, stunted, and in poor health, attributed to lack of circulation, and high soil salinities (Harvey and others, 1986). Approximately 20 percent of the marsh area is bare, probably due to high soil salinities, local ponding, and to patches of sediments with especially high clay content. Although pickleweed is native to the marsh zones above mean tide level, periodic inundation of the soil is thought to be important in providing both soil moisture and regulating soil salinity. Pickleweed growth and reproduction appears to have been adversely affected by the loss of periodic inundation associated with diking off the marsh.

Various parameters are thought to influence pickleweed growth and reproduction. The primary factor(s) are still in debate, but the following parameters are considered to exert the greatest influence on pickleweed growth (Mahall, 1974; Zedler, 1982; Josselyn and Buchholz, 1984; Nuttle, this report).

- Competition from other saltwater and freshwater vegetation
- Soil composition
- Tidal water
- Soil aeration/soil moisture

## TABLE 1
## AREAS[a/] OF NEW CHICAGO MARSH MEASURED AT ONE-FOOT CONTOUR INTERVALS WITHIN SUBDIVISIONS SHOWN ON PLATE 5[b/]

| Sector[c/] | Elevation Intervals in feet, NGVD | | | | | Total Area (ft$^2$) |
|---|---|---|---|---|---|---|
| | 0.0 | 0.0 to -0.1 | -0.1 to -2.0 | -2.0 to -3.0 | -3.0 to -4.0 | |
| 1A | 7730 | 125,790 | 180,410 | - | - | 313,930 |
| 1B | - | 20,970 | 23,720 | 10,480 | 15,450 | 70,620 |
| 1C | - | 8,280 | 41,940 | 10,480 | 20,970 | 81,670 |
| 1D | 14,900 | 25,380 | 41,380 | 53,510 | 35,310 | 170,480 |
| 2 | 5,520 | 100,410 | 114,200 | 105,380 | - | 325,510 |
| 3 | - | 15,550 | 233,930 | 30,350 | - | 280,830 |
| 4 | - | 20,410 | 150,070 | 75,590 | - | 246,070 |
| 5 | 10,480 | 25,860 | 570,000 | 190,900 | 15,450 | 812,690 |
| 6 | - | - | 211,310 | 1,574,620 | - | 1,785,930 |
| 7 | - | 372,410 | 253,800 | 241,100 | - | 867,310 |
| 8 | 30,340 | 256,550 | 726,010 | 311,720 | - | 1,334,620 |
| 9 | - | 80,550 | 602,490 | 273,100 | - | 956,140 |
| 10 | - | - | 430,340 | 176,000 | - | 606,340 |
| 11 | 52,410 | 173,250 | 692,410 | 90,480 | - | 1,008,550 |
| 12 | - | 100,410 | 430,350 | 344,830 | - | 875,590 |
| 13 | - | 45,790 | 189,250 | 265,930 | 55,720 | 556,690 |
| 14 | - | 180,970 | 1,233,090 | 226,210 | - | 1,640,270 |
| 15 | 20,960 | 40,280 | 630,070 | 60,690 | 10,480 | 762,480 |
| 16 | - | 54,620 | 125,800 | 115,860 | - | 296,280 |
| 17 | - | 51,507 | 203,287 | 113,424 | - | 368,218 |
| 18 | - | 139,726 | 791,780 | 404,383 | - | 1,335,489 |
| Channels | | | | | 700,000 | 700,000 |
| Total Sq. Ft. | 142,340 | 1,839,713 | 7,885,637 | 4,675,037 | 962,421 | 15,395,707 |
| **Total Acres** | **3.27** | **42.23** | **181.03** | **107.32** | **22.09** | **353.44** |

a/ - Areas in square feet

b/ - Values are as planimetered; errors of up to several percent may be expected

c/ - See Plate 5 for location of area

- Soil salinity
- Nutrients/reproduction methods

No obvious change in the vigor of the pickleweed was observed due to several weeks of inundation by fresh water following the storms of early March 1983 (H.T. Harvey, pers. comm.).

A very brief outline of each factor is presented below. It should be noted, however, that research in each of these areas is too extensive to be adequately covered in this report, and that agreement among researchers is often lacking.

Competition

Perennial pickleweed is more tolerant of high soil salinities than any other salt marsh plant in San Francisco Bay. This tolerance provides pickleweed an advantage over freshwater species and other halophytes (saltwater species) in the high salinity marsh zones, particularly those found between mean high water and extreme high water. This suggests that significant long-term reduction in marsh <u>sediment</u> salinity levels below a range of 25 to 45 ppt might encourage effective competition by other species which could be disadvantageous to the pickleweed population.

Soil composition

The relation between substrate (soil texture and composition) and vegetation in salt marsh environments is difficult to discern from the effects of various other environmental factors. There is evidence however, that some species of marsh vegetation prefer specific soil types. The annual species of pickleweed grows well in soft mud with subequal silt and clay, and with high organic content. Other evidence suggests a transition from mud/peat to sand and gravel at the transition between <u>Salicornia</u> and <u>Spartina</u> <u>alterniflora</u> (cordgrass) in marshes. Mahall (1974) summarizes: "It appears that soil composition may or may not play an important role in the zonation of vegetation in salt marshes depending on the particular marsh and species involved, and even on the specific location within the marsh. It is probable that salt marsh plants do not respond directly to soil composition alone but respond to other factors such as soil aeration, water contact, or salinity which in turn may be greatly affected by soil composition."

Tidal circulation

The role of tidal water is considered by many researchers an important factor affecting marsh vegetation. Field evidence from Southern California marshes indicate vegetative transition from one species to another with changes in ground height as little as one inch (Mahall, 1974; Zedler, 1982). Elevation relative to mean and extreme high tide levels has been shown to be crucial in the success of pickleweed colonization in Bay Area marshes (Josselyn and Buchholz, 1984; BCDC staff, 1988). This suggests the degree of sensitivity of the vegetation to tidal influences. Pickleweed is thought by some researchers to be less competitive in soils subject to frequent submergence, although other researchers report pickleweed growing in deep water alongside cordgrass (Mahall, 1974). Other studies suggest that pickleweed seedlings are subject to higher mortality rates in the neap tide zones than in the spring tide zones, probably due to mechanical uprooting or reduction in sunlight during submergence.

Soil aeration/soil moisture

Cordgrass has the ability to develop "internal gas spaces" to help transport oxygen to the plant while being partially submerged. Pickleweed, however, has only a partial adaptation for this, and appears to grow best in areas with better drainage which are subject to less frequent flooding (above mean tide and especially above mean high tide). Although pickleweed is tolerant of high soil salinity and low soil moisture "...the vegetation in New Chicago Marsh survives on much less moisture than would be available in an undisturbed marsh under the same climatic conditions by virtue of the occasional flooding of the surface by the spring tides" (Nuttle, p. 7). The effect of the soil moisture on pickleweed has not been adequately researched, although it may be an important factor in pickleweed growth and reproduction.

A test of the hypothesis that waterlogging (low soil aeration) prevented pickleweed from growing below mean high water level indicated that if transplanted, pickleweed can survive readily for at least six months in the cordgrass zone below mean high water. Difficulty in establishment was suggested as the reason for the general absence of pickleweed below mean high water. Both soil aeration and occasional freshwater exposure may be factors in promoting germination below mean high tide, as observed in areas surrounding New Chicago Marsh.

No adverse effect on pickleweed vigor was observed at New Chicago Marsh following several weeks of submergence in floodwaters of very low salinity following the March 1983 overbank events (H.T. Harvey, pers. comm.).

Soil salinity

Soil salinity in salt water marshes has been widely studied. Unfortunately, the results of these studies are often contradictory or inconclusive. The general horizontal and vertical (depth) variation of soil salinity in salt water marshes is described by Mahall (1974): "The salinity increases landward to a maximum at just above mean high water and then gradually decreases." During winter soil salinity increases with depth, while in summer soil salinity decreases with depth, as well as having a higher absolute concentration compared to winter levels. Other factors worth noting:

- Pickleweed is shallow rooted (approx. 10 cm) and therefore subject to the high soil salinity concentrations observed during the summer months

- Average soil salinity is at a maximum during late summer and at a minimum late in the wet season; pickleweed tolerance for the high summer salinities and the annual range of salinity may be the critical competitive advantage for the species

- Pickleweed plant height is inversely related to soil salinity. Pickleweed generally grows better in water with a salinity between 1 and 3 percent NaCl (Mahall, 1974), equivalent to a total salinity of about 12 to 35 ppt, and can tolerate higher soil salinities (e.g., Harvey and others, 1986), although growth and reproductive rates may decrease.

Nutrients

Nutrients are commonly not considered a limiting factor in development and spread of common marsh plants. The hydrologic regime proposed for New Chicago Marsh incorporates considerably lower circulation rates than prevails in most restored tidal marshes. We believe, however, that levels of assimilable nitrogen, phosphorus, potassium, and sulfate will be sufficient to not limit the ultimate extent of Salicornia in the marsh. Nutrient concentrations in the source waters are enriched through the discharge of wastewater effluent. Under the proposed operating plan, intake and circulation of nutrients are likely to be roughly proportionate to seasonal growth patterns. Additionally, organic matter mineralized during the century of isolation from the Bay may provide a substantial leachable nutrient reservoir.

Competition for available nutrients is likely to be exerted by algal growth during the summer months. Ambient levels are likely to be sufficient to support growth of both algae and pickleweed, especially if cross-ditching and other internal circulation measures are implemented. Monitoring for inorganic nutrient levels is incorporated in the plan for water quality maintenance outlined in Chapter 5.

Reproduction and Colonization

Seed germination of marsh vegetation is thought to be dependent on various independent factors such as soil salinity, humidity, diurnal temperature fluctuations and water salinity (Mahall, 1974; Zedler, 1982). In some salt marsh species, vegetative reproduction is thought to be of much greater importance than seed reproduction. Reproduction by seed germination, however, is expected to be the primary mechanism to revegetate the bare areas within New Chicago Marsh (Nuttle, p. 12).

## 3.4 EXISTING MARSH SOIL QUALITY

Surface soil salinity levels in New Chicago Marsh are considered higher than would occur naturally, as a result of the marsh being isolated from tidal action. In natural marsh systems, surface soil salinity tends to increase throughout the dry season as evapotranspiration directs soil moisture and dissolved solids towards the soil surface. The concentrated salts are then flushed from the surface by flood waters, particularly during spring tides. This flushing mechanism leads to lower salinities in the sediment in the area of the marsh that is frequently flooded, and higher salinities in the less frequently flooded areas, in areas above the level of mean high water (Nuttle, p. 6). The highest areas above mean high water in marshes with regular circulation are flushed only a few times a year during the spring high tides.

Soil salinity levels (measured by specific conductance) in 20 samples collected from New Chicago Marsh varied from 32 and 265 mmhos/cm (Appendix D). In general, the bare areas were more saline (mean of 167 mmhos/cm) than the vegetated zones (mean of 97 mmhos/cm) (Harvey & Stanley, 1986). Exchangeable sodium percentages were 49 and 41 percent, respectively, of cation reactance. Average pH values of 5.4 were measured in the bare areas, while mean pH of 4.3 was measured in the pickleweed areas. Minimum pH values of 4.1 were reported. Values of 3.5 to 6.5 are frequently reported in surface sediments at or above the MHHW level in active tidal marshes surrounding the Bay (e.g., Josselyn and Buchholz, 1984); the lower portion of this range is thought to inhibit Salicornia growth.

Extreme soil salinity and low soil moisture have similar effects in depressing or inhibiting pickleweed growth (Nuttle, p. 8). Elevated sediment salinities, for example, are thought to be a primary factor in reduced rates of colonization by cordgrass and pickleweed at the Hayward/Johnson Landing marsh (BCDC staff, 1988). Additionally, gradual and progressive oxidation of the desiccated marsh sediments depresses soil pH. Periodic flooding of the marsh is one means by which the accumulated salts and acidic compounds may be flushed from the surficial sediments. Nuttle recommends that the marsh be flooded to mimic the annual spring tide cycle, with individual flood events lasting two to three hours extended over a three-day period; however, POST and USFWS have chosen not to pursue this course for several reasons. The volumes of water which would need to be pumped to achieve annual flooding are large. Both the capital and operating costs associated with occasional managed flooding are considerable. The required pumping rates, likely to be in the range of 5,000 to 80,000 gallons per minute under various scenarios, could be disruptive both within and beyond the boundaries of the marsh. Finally, the intensity of management exceeds levels currently considered appropriate for large, publicly-owned marshlands.

As an alternative, we suggest that flushing be allowed to progress over a period of years as it would ordinarily occur in a diked area, as an outgrowth of the proposed circulation of tidal waters from near Triangle Marsh, supplemented by freshwater inflow from the small tributary drainage, occasional periods of heavy winter rainfall, and rare regional overbank flooding. Such flushing is projected to be more effective than that which presently occurs, given the improved circulation recommended in this report. Leaching of the salts and acids from the surficial deposits will not be as rapid, nor likely to be as complete, as that achievable under the regime advanced by Nuttle, but may be sustained more reliably at a lesser degree of intervention. A slower and possibly less extensive colonization by Salicornia may develop at the alternative management level that we recommend be considered, but it is more likely to be sustained over the years to provide habitat for the salt marsh harvest mouse.

### 3.5 EXISTING MARSH WATER QUALITY

Unfortunately, the quality of water within New Chicago Marsh has not been extensively studied. Currently, the marsh contains water in both old sloughs and channels, as well as in shallow seasonal ponds. As exemplified by the data collected by the Environmental Education Center's volunteers (Appendix B), salinity of the marsh water varies with locality, season, and year. During the dry season, the marsh water is more saline, while during the wet season, it is less saline. Salinity levels within the marsh will need to be carefully monitored and adjusted throughout the year. Salinity measurements of marsh waters from published sources are presented below (Castillo, 1985, in Harvey & Stanley, 1986, p. 15):

| Location | Date | Water Salinity (ppt) |
|---|---|---|
| Major Slough at West end N.C. Marsh | August 1985 | 105 |
| Major Slough at West end N.C. Marsh | Oct. - Dec. 1985 | 38-56 (mean 44.3) |
| Borrow Channel, North edge of N.C. Marsh | Oct. - Dec. 1985 | 40-31 (mean 36.8) |
| Borrow Channel, North edge of N.C. Marsh | Jan. 14, 1985 | 35-45 |
| Surface of Borrow Channel, North edge of N.C. Marsh | May and June 1983 (following Mar. 2, 1983 flood) | 6.4-7.4 |

Present observations indicate that temperature and salinity stratification develop in certain of the sloughs, especially along the northern margin of the site. Localized deeps within the slough network may encourage stratification. The extent, duration and degree of stratification should be systematically observed during the initial years of operation, as it may affect the population and diversity of aquatic species in the restored marsh; the monitoring program proposed in Chapter 5 provides for such observations. Based on present understandings, the duration and extent of stratified conditions may be sufficiently restricted such that they do not fundamentally affect management goals. This projection should be periodically reviewed with particular attention to the needs of Gambusia and benthic macrofauna.

# 4 DESIGN CONSIDERATIONS

This section outlines various factors which have been considered in determining the recommended design of the hydrologic enhancement program. Each factor is briefly summarized and its application to the New Chicago Marsh project described. Technical information in this section has been abridged from both published and unpublished reports.

## 4.1 ALTERNATIVE WATER SOURCES

In order to hydrologically enhance the New Chicago Marsh environment, an abundant, reliable, economic, and chemically compatible source of water is necessary. Six alternative water-source options which we considered are presented in Table 2. Of the six, water from either Artesian Slough or Coyote Creek near Triangle Marsh appear the most suitable for marsh rehabilitation. Chemical characteristics of these two water sources, and those of other local waters, are compared and contrasted in the following sections.

## 4.2 WATER SALINITY CRITERIA

Salinity is an important water-quality parameter in choosing a supplemental water source for the marsh. Maintaining the recommended typical water salinity of 20 to 30 ppt during spring and summer is desirable for long-term management of the marsh vegetation. Although initially the soil and channel water salinity may be higher than targeted, the best long-term water source should have a salinity near the lower end of this range. The location of four South Bay Discharge Authority NPDES water quality measuring stations in Artesian Slough and Coyote Creek are indicated in Plate 8. Table 3 presents the mean and range of salinity levels measured at the four monitoring stations in 1977, and 1980-1984. Average annual discharges from the water pollution control plant, in millions of gallons per day, are also presented.

# TABLE 2
## WATER SOURCE OPTIONS

| SOURCE | RANGE OF SALINITY (ppt) | REMARKS |
|---|---|---|
| 1) Artesian Slough | 0.5-2.0 | Almost entirely treated wastewater effluent |
| 2) Alviso Slough | 0.5-1.5 | |
| 3) Coyote Creek near Triangle Marsh | 3-13 | Preferred source; appears to vary regularly with tide, generally at lower end of range |
| 4) Leslie Salt Pond A-16 Immediately to North | 75 | Based on two measurements by Debby J. Johnston (Appendix C). |
| 5) Leslie Salt Bitterns | 200-300 ppt | Considered primarily as a contingency source if marsh salinity falls excessively |
| 6) Ground Water | -- | Shallow water salinity: 4 ppt and greater (HEA, in Brown and Caldwell, 1978; 1980). Deep water salinity: unknown. |

## TABLE 3

## ANNUAL SALINITY LEVELS FROM ARTESIAN SLOUGH AND COYOTE CREEK SBDA/NPDES WATER QUALITY MONITORING STATIONS

| NPDES Station[a/] | Sampling Location | Salinity (ppt) 1977[b/] MEAN | 1977[b/] RANGE | 1980[c/] MEAN | 1980[c/] RANGE | 1981[d/] MEAN | 1981[d/] RANGE | 1982[e/] MEAN | 1982[e/] RANGE | 1983[f/] MEAN | 1984[g/] MEAN |
|---|---|---|---|---|---|---|---|---|---|---|---|
| C-1-0 | Artesian Slough | 0.98 | -- | 1.0 | 1.0-9.0 | 1.1 | 1.0-8.0 | 1.1 | 0.0-6.0 | 1.0 | 1.0 |
| C-1-1 | Artesian Slough | -- | -- | 1.7 | -- | 1.1 | -- | 1.1 | -- | 0.9 | -- |
| C-2-5 | Mouth of Artesian Slough | -- | -- | 1.6 | -- | 1.6 | -- | 1.6 | -- | 1.3 | 2.3 |
| C-3-0 | Coyote Creek near Triangle Marsh | -- | -- | 3.8 | -- | 4.1 | -- | 2.9 | -- | 2.0 | 3.6 |
| Mean annual discharge-San Jose/ Santa Clara WPCD (mgd) | | 106 | | 102 | | 110 | | 119 | | | 115 |

a/ NPDES station locations shown in plate 8.
b/ Extreme drought year.
c/ Representative above-normal rainfall year.
d/ Representative below-normal rainfall year, with approximately 38 percent of median annual runoff in Coyote Creek.
e/ Wet, stormy year, 319 percent of median annual runoff.
f/ Extreme wet year, 376 percent of median annual runoff.
g/ Representative normal year, 112 percent of median annual runoff.

## TABLE 4

## COMPARISON OF ARTESIAN SLOUGH AND SALT BITTERNS WITH SAN FRANCISCO BAY WATERS

| Constituent | Artesian Slough (1977) (Brown & Caldwell, 1978) | Leslie Salt Co. Bitterns (1972) | Artesian Slough/ Bitterns Mixture of 10:1 | South San Francisco Bay Representative Waters (Leslie Co., 1972) |
|---|---|---|---|---|
| Ca (ppm) | 61 | 450 | 96.4 | 380 |
| Mg (ppm) | 34 | – | – | – |
| Na (ppm) | 240 | 5,500 | 790 | 7,500 |
| K (ppm) | 19 | – | – | – |
| $HCO_3$ (ppm) | 323 | – | – | – |
| $CO_3$ (ppm) | – | – | – | – |
| $SO_4$ (ppm) | 55 | 21,000 | 1,959 | 2,400 |
| Cl (ppm) | 325 | 158,000 | 14,659 | 17,000 |
| F (ppm) | 2.4 | 74.9 | 8.9 | 1.21 |
| $NO_3$ as N (ppm) | 6.2 | 37.5 | 9.0 | 0.72 |
| $PO_4$ as P (ppm) | 14.0 | 0.22 | 12.75 | 0.41 |
| B.O.D. (ppm) | 5.2 | 198 | 22.7 | 1.2 |
| TDS (ppm) | 988 | 241.550 | 22,857 | 30,587 |
| Salinity (ppt) | 0.99 | 241.6 | 22.9 | 30.6 |

Since 1977 is considered an extreme drought year, the salinity levels presented in Table 3 are an approximation of the water quality which can be expected at the various monitoring stations should a drought of similar severity reoccur. The 1981, 1982, 1983 and 1984 salinity levels are representative of years which experienced 50%, 210%, 230%, and 100%, respectively, of the average annual rainfall. Salinity levels from 1984 are considered an approximation of expected conditions during a year of average precipitation. Year-to-year differences in salinity are relatively small.

Artesian Slough (also known as Mallard Slough) water salinity averages approximately 1.0 ppt, while water from Coyote Creek near Triangle Marsh is typically between 2.0 and 4.1 ppt. Both of these sources are less saline than the target range of 15 to 35 ppt, but they are the most feasibly-divertible waters available. The salinity of diversions from Coyote Creek near Triangle Marsh can be effectively increased to the desirable range within New Chicago Marsh through evaporation.

## 4.3 EVAPORATION AND TRANSPIRATION CRITERIA

Most of the outflow from the marsh will be as evaporation and evapotranspiration, unlike virtually all other restored marshes, where direct discharge to the regional tidal system is feasible. The two processes will affect both the level and salinity of water in the marsh.

Evaporation at New Chicago Marsh is anticipated to follow seasonal patterns similar to that measured at the Newark weather station, approximately five miles to the north. Recent monthly pan evaporation data from Newark are presented in Table 5, and transformed to the equivalent lake evaporation rates using a standard coefficient of 0.70. Net evaporation is negative or approaches negative values during the months December through February and occasionally March. Annual net evaporation is expected to be about 38 inches per year.

Approximately 425 acre feet of annual evaporation is anticipated from the 130 acres of water surface in the marsh. Values of between 410 and 450 acre feet annually are used in subsequent calculations. Evaporation will be offset periodically during the dry season by introducing water from the sloughs, probably at Triangle Marsh. Table 6 presented the approximately monthly volume of water necessary to offset expected evaporation.

# TABLE 5

## MEAN MONTHLY EVAPORATION NEWARK, CALIFORNIA

| MONTH | NET PAN EVAPORATION[a/] (inches) | EXPECTED POND EVAPORATION (70% Pan) (inches) |
|---|---|---|
| January | -0.65 (rain) | negative value |
| February | -0.21 (rain) | negative value |
| March | 1.64 | 1.15 |
| April | 5.72 | 4.00 |
| May | 8.48 | 5.94 |
| June | 10.08 | 7.06 |
| July | 10.00 | 7.00 |
| August | 8.76 | 6.13 |
| September | 7.07 | 4.95 |
| October | 3.75 | 2.62 |
| November | 0.42 | 0.29 |
| December | 0.19 | 0.13 |
| | Expected Seasonal (10-month) Evaporation | 39.27 |

a/ Recent data provided by Leslie Salt Co., are for evaporation net of rainfall, during the 11-year period, 1977 to 1987.

Evapotranspiration is seldom a primary consideration affecting planning for restoring tidal wetlands. In the case of New Chicago Marsh, however, evapotranspiration will exert a supplemental demand upon water introduced in to the marsh. The extent of this demand will be limited to where and when additional water is available for transpiration. At present, pickleweed and other plants in the marsh survive with the local rainfall, averaging approximately 12.5 inches per year, or about one-third of the lake evaporation rate and about one-quarter of the potential evapotranspiration rate of 48.3 inches per year. After restoration, plants within a limited distance from the filled sloughs will have access to additional moisture made available by higher local water tables and perhaps by lateral recharge or capillary transfer from the open water bodies. Work to date (e.g., Nuttle, 1986; Harvey and other, 1987; and Hemond and Chen, 1987) suggest that the former mechanism is of much greater importance, by at least an order of magnitude. This suggests that, in New Chicago Marsh, recharge of the inter-channel water table is likely to occur in winter, when maximum water levels occur during seasonal storms. If so, additional water used by plants is a factor in the annual water budget, but does not add appreciably to the peak inflow requirements during the mid-summer months. In the apparent absence of water-use data for discontinuous Salicornia cover in non-tidal wetlands, we estimate the additional annual water use following restoration to be one-third of lake evaporation rate, or about 140 acre-feet per year in the non-flooded 190 acres.

During June and July, generally the months of greatest evaporation (Table 6), a steady computed inflow of 575 gallons per minute (1.28 cubic feet per second) will be needed to maintain the marsh at a level of minus 2.0 feet. In actuality, inflows are expected to vary with the tidal cycle and with other operational needs and conveniences. Pending further information on detailed design and operational consideration, diversion facilities capable of at least 3 to 3.2 times the steady inflow rate should be incorporated into the project design to allow for such patterns. An effective inflow sizing of approximately 1800 gallons per minute (or about 4.1 cfs) appears appropriate.

## TABLE 6

### INFLOWS REQUIRED TO OFFSET EVAPORATION AND TO INITIALLY FILL NEW CHICAGO MARSH[a]

**Inflow required to offset evaporation:**

| Month[b] | Mean Pond Evaporation (in) | 200 Acre Project (acre feet) | 200 Acre Project (gpm equiv.)[c] | 340 Acre Project (acre feet) | 340 Acre Project (gpm equiv.)[c] |
|---|---|---|---|---|---|
| March | 1.15 | 8.53 | 62 | 12.40 | 91 |
| April | 4.00 | 29.67 | 224 | 43.13 | 326 |
| May | 5.94 | 44.06 | 322 | 64.05 | 468 |
| June | 7.06 | 52.36 | 395 | 76.13 | 575 |
| July | 7.00 | 51.92 | 379 | 75.48 | 552 |
| August | 6.13 | 45.46 | 332 | 66.10 | 483 |
| September | 4.95 | 36.71 | 277 | 53.38 | 403 |
| October | 2.62 | 19.43 | 142 | 28.25 | 206 |
| November | 0.29 | 2.15 | 16 | 3.13 | 24 |
| December | 0.13 | 0.96 | 7 | 1.40 | 10 |
| 10-Month Total | 39.27 | 291.25 | n/a | 423.45 | n/a |

**Inflow required for initial filling[d]**

| | | 200 acre project | 340 acre project |
|---|---|---|---|
| 1. | Estimated volume to raise water level from -5.0 to -3.0 NGVD | | |
| | cubic feet (est.) | 1,275,000 | 1,700,000 |
| | acre feet | 29.3 | 39.0 |
| 2. | Estimated volume to raise water level from -3.0 to -2.0 NGVD | | |
| | | 5,200,000 | 7,400,000 |
| | | 119.0 | 169.9 |

a/ Inflows are based on normal conditions, and may be adjusted at will to account for rainfall, runoff, flood overflows, or other deviations from normal conditions.

b/ Inflows computed for March (and April) assume no net surplus of stored water from rainfall during January and February, when precipitation usually but not always exceeds evaporation; excess inflow can be discharged through the pump system.

c/ Inflow which would produce the equivalent volume, in acre feet, if sustained for 24 hours per day throughout the month; in actuality, design rates approximately 3.2 times greater will be used, due to the limited duration of suitable tidal and salinity levels at Triangle Marsh, and to the anticipated need to offset evaporation during atypically warm periods.

d/ Volumes are based upon water levels sustained at -2.0 feet, or 89 acres (200-acre project) and 129.4 acres (340-acre project) of water surface

During the dry season, salinity levels will rise, and locally may become quite high. High salinity water may be pumped out of the marsh system and replaced by fresher water, or mixed with fresher water and returned to the marsh. The formation of high salinity water pockets within the sloughs and channels either by isolation or stratification is considered to be undesirable, given the management objectives for the marsh. Ditching and mixing are expected to help prevent widespread development of this problem.

### 4.4 WIND

Wind affects the proposed restoration program in a variety of ways:

1. Wind generates waves and induces circulation and mixing of marsh waters. Related effects include erosion of banks, marsh surfaces, and unprotected levees; vertical mixing of slowly-circulating slough waters, inhibiting development of stratification and related water-quality or temperature phenomena.

2. Wind induces turbidity, and increases its persistence.

3. Turbidity, circulation, and oxygen entrainment by wind discourage algal growth, particularly anaerobic algae, which are a management problem.

4. Winds clear algae and floating aquatic growths from larger and windward areas of open water toward leeward areas of more limited circulation.

5. Wind desiccates the marsh surface, and promotes evaporation of pooled waters in salt pans.

6. Wind may affect the dispersal of any odors related to decay of marsh or aquatic vegetation.

7. If marsh circulation is promoted by wind-activated pumps, the net rate of inflow and outflow will be controlled in part by the duration and speed of the wind.

Wind frequency, direction, and duration will also affect other elements of or dynamics in the marsh, such as avian predation or survival of mosquito larvae, but to a more limited extent and in manners not available to direct management. Wind is likely to be a primary circulating force in New Chicago Marsh under normal operating conditions. Typical monthly air-movement volumes at Newark, California are presented in Table 7. The data indicate relatively few days of calm, particularly during the critical summer months. The nearly constant air movement in summer may explain why odors and their dispersal were not substantively considered as part of the environmental impact report for wastewater disposal and reclamation at the neighboring San Jose/Santa Clara Water Pollution Control Plant.

Winds are, however, probably not sufficiently consistent or strong to support high-volume pumping, which calls for sustained wind speeds exceeding 9 miles per hour, or preferably 14 mph. During May, the windiest month, wind speeds average about 5.7 mph.

To the extent that algae or floating aquatic plants do develop in the marsh, they are likely to be blown southeastward toward the heads of the relict sloughs. Observation is warranted to establish the extent and duration of stratification at the water levels proposed for the operation of the restored marsh. We suggest that this be evaluated during the initial year under actual operating conditions.

## 4.5 WATER AND SALINITY BUDGETS FOR RESTORED NEW CHICAGO MARSH

Water and salinity budgets for a restored marsh of 340 acres, operated at a steady level of -2.0 feet, are presented in Tables 8 and 9, respectively. Both tables are based on mean rainfall and evaporation data; however, differences are not large for expected year-to-year variations, with the important exception of rare flooding events which overtop or breach the levees.

Flows into and out of the marsh are about 720 acre feet per year, or about four times the volume of water in the marsh when maintained at a level of -2.0 feet. Atypical of tidal marshes, most of the outflow is as evaporation and evapotranspiration. As a result, salts and other constituents will gradually be concentrated in the marsh. The rate of concentration is projected to range from 200 to 4800 tons per year, resulting in an annual increment of about 3000 to 30,000 milligrams per liter (3 to 30 ppt salinity), with the lower end of this range being more likely.

# TABLE 7

## AIR MOVEMENT BY MONTH, SOUTH BAY AREA

| | Wind Index[a] | Mean Wind Speed Equivalent (mph) | Percent of Annual Total[a] (percent) | Percent of Time of Calm[b] (percent) |
|---|---|---|---|---|
| January | 1453 | 2.0 | 3.82 | 9 |
| February | 2467 | 3.6 | 6.49 | 7 |
| March | 3706 | 5.0 | 9.76 | 4 |
| April | 3793 | 5.3 | 9.98 | 3 |
| May | 4231 | 5.7 | 11.14 | 3 |
| June | 3985 | 5.5 | 10.49 | 3 |
| July | 3738 | 5.0 | 9.84 | 3 |
| August | 3101 | 4.2 | 8.16 | 3 |
| September | 3213 | 4.5 | 8.46 | 5 |
| October | 2497 | 3.6 | 6.57 | 5 |
| November | 2594 | 3.6 | 6.82 | 9 |
| December | 3211 | 4.3 | 8.45 | 9 |
| Annual Total | 37,989 | = 4.3 mph | | |

a/ Index is the amount of air movement over evaporation pan, in miles per month. Data for period of intensive agroclimatic monitoring at Newark pan-evaporation stations (1966 and 1967); Alviso is considered by USFWS biologists to be somewhat windier.

b/ Data for Oakland International Airport (c.f., Nolan and Fuller, 1986); Alviso is considered to have a greater frequency of windy days than the recording station.

## TABLE 8

## ASSUMED WATER BUDGET FOR RESTORED NEW CHICAGO MARSH, YEAR OF NORMAL RAINFALL[a]

| | Water Surfaces (130 ac.)[b] | Other Areas Within Marsh (190 ac)[b] | Southeastern Contributing Area (170 ac.)[b] | Total |
|---|---|---|---|---|
| Inflows | | | | |
| Rainfall | 0[c] | | | 0 |
| Runoff | -- | 158 afa[d] | 21 afa[e] | 180 afa |
| Triangle Marsh | | | | 515 afa [h] |
| Artesian Slough | -- | 25[f] | -- | 25 afa |
| subtotal | -- | | | 720 afa |
| Outflows | | | | |
| Evaporation | 420 afa | -- | -- | 420 afa |
| Evapotranspiration | -- | 200[g] | -- | 200 afa |
| Outlet Discharge | -- | -- | -- | 100 afa [h] |
| subtotal | | | | 720 afa |
| Net | | | | 0 afa |

a/ All units in acre feet per year; totals may differ from sums of components due to rounding
b/ From "Goals and Objectives For Design" chapter
c/ Included in evaporation computations
d/ Assumes 2.5 inches of rainfall needed to meet seasonal soil-water deficit before runoff occurs from non-inundated areas within the marsh
e/ Based on 1.5 inches per year of runoff
f/ Water needed to offset evapotranspiration in 8 acres of freshwater marsh; additional inflow from near Triangle Marsh can be substituted if the freshwater marsh is not constructed
g/ Estimated as one-third of evaporation rate, averaged over the 190 acres of non-flooded ground in the marsh
h/ Assumed average; actual value will be adjusted to meet water level needs

## TABLE 9

## ASSUMED SALINITY BUDGET FOR RESTORED NEW CHICAGO MARSH: YEAR OF NORMAL RAINFALL

| | Volume of Water (afa) | Salinity (ppt) | Salinity[a] Loadings (tons) |
|---|---|---|---|
| Inflows | | | |
| Rainfall | | neg | neg. |
| Runoff | 180 | 0.2 | 50 |
| Triangle Marsh | 515[b] | 3 to 13 | 2100 to 9100 |
| Artesian Slough | 25 | 1.5 | 50 |
| Subtotal | | | 2200 to 9200 |
| Outflows | | | |
| Evaporation | 420 | neg[c] | neg |
| Evapotranspiration | 200 | neg | neg |
| Outlet Discharge | 100 | 15[d] | 1360 |
| Subtotal | | | 1360 |
| Net Inflow | | | 800 to 7800 |

a/ Salinity of 1.0 ppt = 1000 ppm TDS = 1.36 ton/acre ft.
b/ Assumed values; actual value to be adjusted to meet water-level needs
c/ Removal form the marsh in gaseous phase may be a significant factor in the budgets for individual constituents, such as nitrogen
d/ Assumed volume-weighted mean salinity; time-weighted average salinity will be lower, since the pumps will discharge mainly in winter

The lower values are considered most probably, based on the limited information presently available for salinity variations at Triangle Marsh.

### 4.6 SEDIMENTATION

Sedimentation is frequently a concern in restoring tidal marshes within the Bay/Delta system. The volume of Bay water introduced annually into New Chicago Marsh will be less than one one-thousandth of the water flowing into marshes in which tidal circulation has been restored. Sediment will be introduced proportionately. We compute estimated sedimentation rates of less than 0.001 feet per year, even neglecting outflow through the pumps.

### 4.7 SALINITY MANAGEMENT

We anticipate that salinities within the desired range of 15 to 35 ppt may be sustained in the marsh due to gradual leaching of accumulated salts and to concentration by evaporation. With experience, desired salinity ranges may be sustained through control of the circulation system. Salinity may be increased, if warranted, by several means, including:

1. Reducing outflow to facilitate evaporative concentration

2. Recirculation of high-salinity bottom waters if stratified conditions develop

3. Introducing inflows from Triangle Slough at tidal stages when it is at maximum salinity

4. Addition of small admixtures of local ground waters*

5. Diverting small volumes of partially-concentrated brines from the pond directly north of the marsh, where salinities appear to range from about 70 to 85 ppt*.

An additional alternative which might also be considered is blending with salt bitterns. Available public data describing the composition of bitterns are presented in Table 4. If Artesian Slough water is mixed at a 10:1 ratio with the Leslie bitterns, the salinity of the resultant mixture may be approximately 23 ppt. The addition of

* Likely contingency measure requiring additional analysis or work prior to implementation.

bitterns also may increase the concentration of other constituents such as phosphate, nitrate, fluoride, or parameters such as biological oxygen demand. The feasibility of blending bitterns remains to be established, and an economical means of delivery to the site must be found. Hence, this intensive management alternative is deemed less desirable as a contingency measure for sustaining salinities.

Excessive salinity levels in marsh waters -- above 45 ppt -- are not expected under normal operations, but could occur during the first years of operation or under certain unusual conditions. Salinities may be lowered by increasing inflow of low-salinity waters and correspondingly raising the rate of discharge. Circulation may also be modified to adjust salinity levels. Effective monitoring of salinity will allow great flexibility in operations, provided both inflows and outflows can be adjusted for salinity control.

## 4.8 TRACE ELEMENT AND NUTRIENT CONSIDERATIONS

Although the salinity levels of marsh soils and water often exert a dominant influence on plant colonization, other constituents need to be considered, such as nutrients and trace elements.

Nutrients will enter the waters of the restored marsh primarily with the water introduced to offset evaporation, and by dissolution of soil nutrients mineralized during a century of isolation from the bay. Nitrate and phosphate levels in local waters are elevated by factors of about 30 and 60, respectively, relative to those in the bay due to the large quantity of effluent from the San Jose/Santa Clara Water Pollution Control Plant. Table 10 presents and compares the levels of major constituents--including nutrients--reported in effluent and local waters. Since effluent concentrations can vary with climatic conditions, as well as treatment design and operation, results from dry, normal and wet years are presented.

Nutrient concentrations at various locations in the area are compared in Table 11. Concentrations of nitrate and phosphate in Coyote Creek near Triangle Marsh are about one-third those found in Artesian Slough. Assuming these values are representative and that little denitrification occurs within the marsh, waters pumped from Triangle Marsh would add about 5 to 6 pounds per wetted acre of both nitrate-nitrogen and phosphate-phosphorus. A similar input is expected from the soils, at least during the initial years. The total net additions are small relative to plant uptake; they are, however, sufficient to support considerable growth of algae. Careful monitoring of the major sloughs during the summer months to describe the factors conducive to algal growth is recommended, so that control measures may eventually be adopted if needed. Biologists familiar with the marsh note that algae blooms presently occur, but are considered manageable.

## TABLE 10

## MAJOR CONSTITUENTS OF WATERS NEAR NEW CHICAGO MARSH

| | SJ/SC Effluent 1977 (very dry year) | SJ/SC Effluent 1984 (normal year) | SJ/SC Effluent 1983 (very wet year) | Mean of Bay Waters[a] | Solar Pond Bitterns[a] | Local Shallow Ground Water[b] |
|---|---|---|---|---|---|---|
| Specific Conductance (umhos) | 1,744 | -- | -- | -- | -- | 26,250 |
| pH (units) | 7.8 | 6.7-7.9 | 7.4 | 8.1 | 7.8 | 8.0 |
| Calcium (mg/l) | 61 | -- | -- | 380 | 450 | 570 |
| Magnesium (mg/l) | 34 | -- | -- | -- | -- | 1,080 |
| Sodium (mg/l) | 240 | -- | -- | 7,500 | 5,500 | 3,240 |
| Potassium (mg/l) | 19 | -- | -- | -- | -- | 5.7 |
| Bicarbonate (mg/l) | 323 | -- | -- | -- | -- | 639 |
| Sulfate (mg/l) | 55 | -- | -- | 2,400 | 21,000 | 1,690 |
| Chloride (mg/l) | 325 | -- | -- | 17,000 | 158,000 | 206 |
| Nitrate - N (mg/l) | 6.2 | 10.7-19.6 | 15.2 | 0.72 | 37.5 | 8.0 |
| Ammonia - N (mg/l) | -- | 0.9-1.5 | 1.7 | -- | -- | -- |
| Kjeldahl Nitrogen - N (mg/l) | -- | -- | -- | -- | -- | -- |
| Orthophosphate - P (mg/l) | -- | 11.7-21.9 | -- | -- | -- | -- |
| Total Phosphate - P (mg/l) | 14 | -- | 12.5 | 0.41 | 0.22 | -- |
| Fluoride (mg/l) | 2.4 | -- | -- | -- | -- | -- |
| Boron (mg/l) | 0.6 | -- | -- | -- | -- | 2.4 |
| Total Dissolved Solids (mg/l) | 988 | -- | -- | 30,587 | 239,790 | -- |

a/ Leslie Salt Company, 1974 analyses.

b/ Ground water at 4 feet depth, Alviso Park (HEA, 1980); shallow ground water in marsh is expected to have similar relative composition, although perhaps at higher concentrations.

## TABLE 11

## NUTRIENT DATA FOR ARTESIAN SLOUGH, COYOTE CREEK AND SAN FRANCISCO BAY

| Location | Nitrate as N (mg/l) | Phosphate as P (mg/l) | Reference |
|---|---|---|---|
| Artesian Slough 1983 | 15.2 | 12.50 | Walker and Assoc. 1984 |
| Artesian Slough 1984 | 15.0 | 13.70 | Walker and Assoc. 1984 |
| Coyote Creek 1984 | 5.1 | 6.0 | Walker and Assoc. 1985 |
| Mouth of Coyote Creek 1984 | 2.5 | 3.4 | Walker and Assoc. 1985 |
| South San Francisco Bay 1982-1983 | 1.8 | 1.5 | Walker and Assoc. 1985 |
| South San Francisco 1983-1984 | 1.2 | 1.6 | Walker and Assoc. 1985 |
| Northern San Francisco Bay, September 1984 (range of values) | 1.1-5.7 | 1.96-2.68 | Ota and others 1986 |
| Northern San Francisco Bay, October 1984 (range of values) | 1.2-6.4 | 2.16-2.49 | Ota and others 1986 |
| Leslie Salt Corporation Bitterns | 37.50 | 0.22 | Leslie Salt Co. 1972 |

Table 12 presents the trace element chemistry of water from the New Chicago Marsh area, as well as water-quality agency water quality objectives for trace element constituents. Although some constituents, such as nickel, exceed regulatory standards, the background level of natural waters (San Francisco Bay) also exceeds these levels. In coastal Northern California, geologic conditions result in natural waters which exceed national water quality objectives for elements such as nickel and mercury.

An inventory of the approximate total mass of copper, chromium, nickel and zinc in the top 15 cm of marsh top soil is presented in Table 13. The top 15 cm represents the depth to which bioturbation and wave action might be expected to expose trace elements in the soil to the marsh water. The predicted loading to the marsh of these four trace elements, if SJ/SC sewage effluent is used, is also presented. For example, the annual loading of copper to the marsh from the effluent would be approximately 0.25% (15,000/6,000,000) that of the copper already present in the upper 15 cm of marsh soil. Comparable data are not available for Triangle Marsh, but are likely to be lower than in Artesian Slough, where effluent constitutes virtually all of the flow, based on fragmentary available data in the SBDA monitoring reports.

The calculated annual vegetative uptake of these metals, also shown in Table 13, is on the order of 8 to 25 percent of the annual inflow.

Net accumulation of trace elements in the marsh is expected based on these estimates. The rate of anticipated accumulation, if all inflow were to remain in the marsh, is approximately one-quarter of one percent of the quantity in the upper 15 cm of the soil. Some of the trace-constituent inflow will be returned to the slough system; most of the rest is likely to be incorporated in mineral sulfides and hydrous oxides, as reduced conditions in the restored marsh sediments come to be more fully developed. These forms are generally not available for uptake by <u>Salicornia</u> or other primary producers; some decrease in existing bioavailability of transition metals is actually expected as the reduced conditions become established. Nonetheless, occasional foliar analysis of pickleweed is suggested as a means of assessing whether accumulation of trace metals in perennial species is occurring over time.

### 4.9 SURFACE MANAGEMENT

Following annual flooding of the marsh, unvegetated areas of New Chicago Marsh should slowly revegetate naturally. The revegetation process can be accelerated by tilling (reaeration) the barren soils to a depth of approximately ten centimeters, enhancing removal of excess salt and creating better conditions for revegetation. Experimental cultivation led to substantially greater rates of pickleweed growth in North Bay marshes (Josselyn and Buchholz, 1984). Without tilling, revegetation of the barren areas may take several years (Faber, 1983). Tilling is not generally recommended for New Chicago Marsh in light of the cost, potential impacts, and generally too-intensive degree of management. We suggest that tilling be considered only as a contingency approach for spot usage.

## TABLE 12
## COMPARISON OF WATER QUALITY GOALS AND STANDARDS FOR SELECTED TRACE ELEMENT CONSTITUENTS[a] WITH REPRESENTATIVE WATERS NEAR NEW CHICAGO MARSH
### (total concentrations in milligrams/liter)

| | As | Cd | Cu | Cr | Hg | Ni | Zn | Reference |
|---|---|---|---|---|---|---|---|---|
| I. Water Quality Goals and Standards | | | | | | | | |
| RWQCB Proposed SF Bay Water Quality Objective | 0.036 | 0.010 | 0.0029 | 0.050 | 0.00002 | 0.0071 | 0.058 | RWQCB, 1986, Ritc. |
| RWQCB Proposed SF Bay Water Quality Objective | -- | 0.0093 | -- | -- | -- | 0.0071 | 0.058 | Anderson, 1986 |
| SWRCB Not to Exceed In Marine Waters | -- | 0.03 | 0.03 | 0.05 | 0.0002 | 0.002 | 0.20 | SWRCB, 1975 |
| EPA, to Protect Saltwater Aquatic Life | 0.063 | 0.012 | 0.002 | 0.054[b] | 0.0001 | -- | -- | Fed. Reg., 1984 |
| EPA, to Protect Saltwater Aquatic Life | 0.508 | -- | 0.004 | 0.018[b] | 0.00002 | 0.0071 | 0.058 | Fed. Reg., 1980 |
| II. Analyses of Waters Near New Chicago Marsh | | | | | | | | |
| Artesian Slough (SJ/SC effluent) | | | | | | | | |
| Dry Year (1977) | 0.0043 | 0.005 | 0.03 | 0.02 | 0.0001 | 0.16 | 0.06 | Brown&Caldwell,1978,& |
| Normal Year (1984) | 0.003 | 0.006 | 0.024 | 0.01 | <0.0001 | 0.034 | 0.05 | Walker Assoc.1985 |
| Wet Year (1986) | 0.004 | 0.002 | 0.011 | 0.003 | <0.0002 | 0.023 | 0.036 | Discharge Reports filed by SJ/SC WPCP |
| Coyote Creek Below Artesian Slough | | | | | | | | |
| Normal Year (1984 Max) | -- | 0.03 | 0.025 | 0.020 | 0.0015 | 0.035 | 0.055 | Walker Assoc, 1985 |
| San Francisco Bay | | | | | | | | |
| Lower South Bay | -- | 0.00034 | -- | -- | -- | 0.015 | 0.013 | RWQCB, 1986 And. |
| SBDA Monitoring Site SB5, 1984 | -- | 0.0092 | 0.0128 | 0.0123 | <0.0001 | 0.047 | 0.0145 | Walker Assoc 1985 |
| SBDA Monitoring Site SB5, 1983 | -- | 0.002 | 0.024 | 0.024 | 0.006 | 0.0002 | 0.033 | Walker Assoc 1984 |
| Representative Urban Runoff | | | | | | | | |
| Dry Season 1984, Fremont Stormwater | -- | -- | <0.02 | -- | -- | <0.03 | 0.27 | Chan-Meiorin, 1986 |
| Dry Season 1985, Fremont Stormwater | -- | -- | <0.01 | -- | -- | 0.04 | ____ | Chan-Meiorin, 1986 |
| Wet Season 1985, Fremont Stormwater | -- | -- | 0.002 | 0.012 | 0.051 | -- | ____ | Chan-Meiorin, 1986 |

a/ Other trace elements are reported at concentration well below currently recognized thresholds of concern.

b/ Hexavalent chromium.

## TABLE 13

## INVENTORY, LOADING, AND PROBABLE UPTAKE OF TRACE ELEMENTS, NEW CHICAGO MARSH

| | Marsh Soils | | Water Inflow | | Vegetative Matter | |
|---|---|---|---|---|---|---|
| | Assumed Concentration (ppm) | Content[a] of Uppermost 15 cm (gm) | Assumed Concentration (ppm) | Annual Loadings[b] (gm) | Assumed Mean Concentration (ppm) | Annual Uptake[c,d] (gm) |
| Copper | 20 | 6,000,000 | 0.024 | 15,000 | 7.5 | 2750 |
| Chromium | 100 | 30,000,000 | 0.010 | 6,300 | 10.0 | 3650 |
| Nickel | 80 | 24,000,000 | 0.034 | 21,500 | 5.0 | 1800 |
| Zinc | 60 | 18,000,000 | 0.05 | 32,000 | 20.0 | 7300 |

a/ Assuming a mean dry density of 1.4 and a depth of 15 cm over 340 acres.
b/ Assuming net annual inflow of 515 acre feet with negligible input from rainfall and local runoff computations, based on concentrations in San Jose/Santa Clara effluent, probably overstate actual anticipated loadings from Triangle Marsh.
c/ Assuming primary productivity of 300 g/m$^2$ or 365 metric tons for 300 vegetated acres.
d/ Estimated from data presented in Tables 30, 31, 32 of Chan Meiorin, 1986; values are generalized and intended for planning purposes only.

# 5 PROPOSED OPERATING PROGRAM

We recommend that water from Coyote Creek near Triangle Marsh be used for the New Chicago Marsh enhancement project. This water, although fresher than desired, is the most saline and economically available water for the project. In addition, any unforeseen problems associated with using treated effluent from the San Jose/Santa Clara Water Pollution Control Plant can be reduced by using the more mixed and saline water from Triangle Marsh.

We also recommend that facilities be installed in two phases. The initial phase should include construction of the inlet works, the outlet facilities, and the master lateral (with feed pipe and spill ports such as flashboard weirs) to promote circulation. It should also include implementing the monitoring program outlined in Chapter 5. A second phase, to be carried out once initial operations have satisfactorily commenced, will include full automation and telemetric instruction of controls at the inlet and outlet, and creation of small freshwater and transitional marshes near the visitor center. If funding allows, construction of an observation tower is envisioned when the prior work elements are completed and the restored marsh is functioning as intended.

Emphasis in this chapter is on the first phase.

## 5.1 OPERATING HYDROLOGIC REGIMEN

The proposed monthly operation of the restored marsh, the envisioned circulation, and the conceptual plan for facilities to implement these plans are described in this section and summarized in Table 14. Because the operating regimen is intended to be highly interactive with ongoing monitoring results, the outline of the monitoring plan follows immediately in the same chapter.

### 5.1.1 SUMMARY OF DESIGN CRITERIA AND CONSTRAINTS

The primary design criteria identified in the previous chapters may be summarized as follows:

1. Maintain water levels at a constant level of minus 2.0 feet, plus or minus 0.2 feet for short-term fluctuations induced by winter storms
2. Salinity is to be maintained between 15 and 45 ppt, especially during the summer months

**Table 14**
**Normal Operating Regimen By Month**
**Proposed for Restoration of New Chicago Marsh**[a/]

| Month | Operating Level (elevation) | Estimated Inflows[b/] (ac. ft.) | Representative Outflows[c/] (ac. ft.) |
|---|---|---|---|
| January | -2.0[d/] | e/ | f/ |
| February | -2.0[d/] | e/ | f/ |
| March | -2.0[d/] | 17.8 | 3 |
| April | -2.0 | 62.0 | 9 |
| May | -2.0 | 91.9 | 11 |
| June | -2.0 | 109.2 | 11 |
| July | -2.0 | 108.3 | 11 |
| August | -2.0 | 94.9 | 10 |
| September | -2.0 | 76.6 | 8 |
| October | -2.0 | 40.6 | 5 or 30[d/] |
| November | -2.0[d/] | 4.5 | f/ |
| December | -2.0[d/] | 2.1 | f/ |

a/ Actual operation will be interactive, with responses to changes in water level and salinity as described in text.

b/ Inflows, except as otherwise indicated, are intended to offset evaporation plus outflows, and may vary.

c/ Outflows, except as indicated for winter months, are initially intended to be approximately 10 percent of inflows. Actual value may vary from 10 percent (or less) to 30 percent based on experience and on considerations described in text.

d/ As an alternative operating rule, water levels may be drawn down to -2.2 feet beginning with the onset of significant runoff (perhaps November 15), and raised to -2.0 at the end of the rainy season (March 15 to early April, depending on the year)

e/ Inflows not anticipated during winter months, as none is required to meet water-balance requirements; inflows, if any, will be driven by salinity or habitat considerations (see text).

f/ Intermittent outflows as needed to sustain water levels at operating level following storms, or to control salinity and/or promote mixing of water in the marsh.

3. Circulation is required in the main sloughs to prevent certain odors and problems, while also maintaining desired salinities.

Principal constraints on operation, other than the infeasibility of restoring tidal circulation, include:

1. Minimal levels of manipulation are desired, to the extent feasible
2. Only tide, gravity, solar and wind power is available for driving inflows; outflows will require power from the commercial electrical grid
3. Inlet regulating works are to be powered by solar cells, batteries, or wind; are to be minimally susceptible to vandalism; and are to be of low total cost
4. Pumps at the outlet are also expected to drive circulation within the marsh when not needed to pump water up and out into the Artesian slough
5. The marsh and all facilities must be able to withstand rare but expected regional flooding.

5.1.2 CIRCULATION

Water will be introduced into the marsh primarily from the slough system adjoining Coyote Creek, near Triangle Marsh. Discharge from the restored marsh will be driven by three high-volume low-head positive displacement pumps driven by electric motors, rated to move 1000 to 1500 gpm against anticipated mean (discharge-weighted) heads averaging 2 to 3 feet. Valves at the inlet and at the windmill will be regulated primarily to sustain water levels within the marsh at a constant elevation of approximately minus 2.0 feet. Once this level is sustained, the inflow and outflow rates will be based upon those needed to maintain desired salinity ranges.

As presently envisioned, flows will enter at the northwestern corner of the marsh from the Triangle Slough, and be discharged near the southeastern corner into Artesian Slough. Water-level and salinity sensors will be emplaced at the discharge pump, and may be accessed through phone lines or radio telemetry via a personal computer. Valves at the inlet and outlet works will be operated by telemetric instruction, so that water levels and salinity may be concurrently regulated.

Plate 9 describes the location of key inflow, outflow and internal circulation facilities within New Chicago Marsh itself.

5.1.2.1 Inflows: Water will enter the restored marsh by rainfall, runoff from contributing areas primarily to the southeast, by inflow from Triangle Marsh and by inflow from Artesian Slough. The first two sources will remain uncontrolled. During major winter storms, water levels may increase from 0.2 to 0.5 feet above winter maintenance levels. Discharge and evaporation is expected to subsequently lower water levels at a rate of approximately 0.035 to 0.055 feet per day. This seasonal rise is expected to be an important element in leaching salts from the upland soils, and also in raising the water table beneath inter-channel areas which do not exchange water laterally with the sloughs at other times of year. Both processes, we believe, are likely to promote the vigor and extent of <u>Salicornia</u> growth, at least initially, and should be encouraged to the degree allowed by vector-control considerations (Collins and Resh, 1989). Fluctuations of water level during the non-storm months are not expected, other than minor diurnal fluctuations.

We suggest that the primary source of inflow be from near Triangle Marsh, where an inlet structure at the southern end will allow flow along the drainage ditch east of the railroad into the northwestern corner of New Chicago Marsh (Plates 10, 11). Annual inflows are expected to vary from about 450 to 600 acre feet per year, varying with seasonal evaporation and with the rate of discharge from the marsh. In most years, inflows are expected to occur from March or April through November or December, depending upon weather and conditions within the marsh. Except during dry years, inflows from near Triangle Marsh during the winter may not be desirable, as a surplus of water within the marsh is expected and salinities at Triangle Marsh may be at their annual lows. This seasonal hiatus will also allow maintenance of the intake works and drainage ditch. Alternatively, winter inflows may be encouraged as a means of reducing salinity, if needed, or to promote wildlife use of the inflow corridor or for other habitat considerations. Seasonal peaks in diversion from Triangle Marsh are expected during June and July. The rate of inflow will vary with tidal stage, averaging approximately 575 gallons per minute. Daily peak flows averaging about 1400 gpm and occasionally reaching 1800 gpm should be accommodated in the design of the inlet works to allow for the cyclic inflows from Triangle Marsh.

If and when implemented during the second phase, a freshwater marsh area of between eight and nine acres near the Environmental Education Center can be sustained by inflows from Artesian Slough. An additional five to six acres of transitional brackish wetland will also be partially supplied from this source.

Maximum monthly inflow rates of about 120,000 gallons per day (about 85 gpm) will be needed to meet the evaporation and transpiration demand exerted by an equivalent of 11 acres of freshwater wetland. The existing pipes through the eastern levee may have sufficient capacity to convey these flows, if gated or valved. This inflow would be manually operated. Overflow should drain into the brackish area and then into the main section of New Chicago Marsh.

5.1.2.2 Internal Circulation: The operating plan assumes only minor differences in water level and salinity throughout the approximately 340 acres of salt marsh. Excavation and limited ditching work at selected locations throughout the marsh (Plate 9) will be needed to promote the required circulation. The primary cross-connection will be a master lateral along the southern perimeter of the marsh. Water will be supplied to the ditch by the outlet pumps when outflow to Artesian Slough is not needed, through a 10-inch pipe extending southward to Grand Avenue through the slough system. Circulation into the interior will utilize the network of relict sloughs which occur throughout the site. The sloughs will also be interconnected at selected locations along the railroad grade bisecting the site, and along Grand Avenue at its southern boundary.

Subsequent modifications to the internal circulation system may occur following observation of the initial restoration efforts. These are expected to be smaller cross-connections, constructed with a Ditch-Witch or similar equipment. Cross-connections of this type should be between channels of approximately equal order, to avoid erosion and deposition associated with adjustment of newly-linked channels of markedly different sizes. When connecting channels of somewhat different size, the alignment should be directed obliquely to contours, with the smaller channel upgradient.

5.1.2.3 Outflows: Water will be discharged from the marsh into Artesian Slough by three electrical positive displacement pumps each with 500 gpm capacities, located near the southeastern corner of the marsh (Plate 9). It is possible that the pump used to drive the internal circulation may be driven by a windmill, as an alternative. Outflows will be conveyed beneath Grand Avenue and through the levee in an 18-inch pipe, spilling to a rubble-covered apron in Artesian Slough (Plate 12). The entrance to the outlet channel should be designed or modified to inhibit sedimentation or debris accumulation; however, periodic maintenance will be needed.

Outflows will be regulated to sustain the water level at the specified elevation. They are rated for discharges of about 1500 gpm, with about 3 feet of head, which will vary with tidal stage. If sustained for a day, pumping at rated capacity results in outflows of approximately 2.16 million gallons per day, or about 6.6 acre feet. When inflows are curtailed, the pump is rated for changing the level in the 130 acres of water surface at a rate of approximately 0.051 feet per day.

### 5.1.3 DESIGN ELEMENTS

5.1.3.1 Inlet Works: Inlet works, outlined in Plates 10 and 11, include:

a. An entrance channel approximately 90 feet long, cleared and excavated to an elevation of +1.0 NGVD

b. Culvert or culverts capable of passing peak flows of 1800 gpm, with inlet invert at elevation 1.0, and outlet invert at elevation -1.0

c. Culvert afterbay, with erosion-control provisions and tailwater weir or energy dissipator approximately 100 feet downstream

d. Repair of cross-levee, using fill from a., b., and c., above

e. Slide gate with combination hand wheel and motor drive capable of operating at instantaneous flows of between 40 to 1800 gpm

f. Controls and power source for gate

g. Telemetry system (transmitter, receiver, antennae) directed at outlet-works control

We also suggest that a debris collector or trash rack be installed at the upstream end of the entrance channel both to protect the valve and inlet system, and to prevent entrainment of plastics and other debris into the marsh.

5.1.3.2 Outlet Works: Outflow will be directed through an 18-inch reinforced concrete pipe into Artesian Slough (Plate 12). The pipe will be laid in an excavation extending from the pump bank to the slough through existing fill, and then beneath Grand Avenue. Power lines to the pump will be routed through conduit placed in the same ditch, with a service and metering vault near the existing undergrounded lines to the Environmental Education Center. Check valves and surge protection between the pumps and Artesian Slough will prevent backflow during rising tides.

Approximately 40 to 50 cubic yards of the existing fill material will be spread in a 12-foot corridor between the base of the existing fill and the pump bank to allow periodic servicing or removal of sediment by backhoe. The pumps, driven by motors mounted above elevation 3.0 on metal frames, are of the positive-displacement type, rated for suction of 15 feet, nearly twice the maximum expected value.

5.1.3.3 Excavations: Excavation will be required at the inlet works, within the marsh to promote circulation, and at the pump bank discharging to Artesian Slough. The volume and means of excavation are outlined in Table 15 by work area.

5.1.3.4 Telemetry and Controls: The nature of the restoration program is such that a continuous record of water levels and salinity at both the inlet and outlet will be needed to assess its efficacy. Continuous water level and salinity sensors which read to field microcomputers (known as dataloggers), make it possible to obtain and analyze a continuous record of this type at reasonable cost. In the second phase, these sensors, read via telemetry by USFWS staff, can be fitted to drive valves and direct flows. During the first years, weekly to monthly patrolling and monitoring by staff may defer the need for full automation.

## Table 15. Proposed Excavation Areas, Volumes and Methods, New Chicago Marsh Restoration[a/]

| Excavation Area[b/] | Volume of Excavation (cu. yd.) | Disposal Method | Remarks |
|---|---|---|---|
| A. Triangle Marsh Inlet Area | @ 56 (to +1.0) | Loader | Cross-levee repair (cut/fill balance) |
| B. Stilling basin for pump bank | 60 to 100 | Loader | Spread over adjacent existing fill area |
| C. 10-inch pipe feeding perimeter ditch | 20 to 40 | Loader or Ditch Witch | Backfill in place where trenching is in fact needed |
| D. Perimeter | 600 to 800 | Ditch Witch or Sprite | Sidecast to improve conveyance and hydraulic properties of the peripheral ditch |
| E. Rubble apron at outlet | 60 to 80 | Loader or long-arm backhoe | Spread over adjacent existing fill |
| TOTAL | 750 to 950 | | |

a/ See Plate 10 for detailed locations of excavation sites
b/ Additional 150 cu yds +/- in existing fill for trenching and backfill of outlet pipe (see Plate 12).

## 5.2 MONITORING PROGRAM

Monitoring at New Chicago Marsh is expected to be an integral part of both operations and maintenance, especially during the initial equilibrating period of three to five years. Monitoring is intended to identify whether the restored marsh can be operated as intended, whether the desired response of pickleweed cover and wildlife use is observed, the degree to which potential problems described above may develop, the rate at which leaching of salts from the marsh sediments stabilizes, and whether other constraints will develop. Monitoring is also directed at responding to and documenting the episodes or contingencies which may arise. A summary of the goals and elements of the monitoring program is presented in Table 16.

### 5.2.1 FREQUENCY OF MONITORING

Monitoring of the environmental processes occurring in the restored marsh may best be accomplished at four separate frequencies:

| | |
|---|---|
| Continual: | Water level at the inlet and outlet works<br>Water temperature at the outlet works<br>Salinity at the outlet and inlet works |
| Daily to Weekly: | Salinity at various locations around and within the marsh (eventually monthly)<br>Water levels and specific conductance at outlet works (for calibration of recording system)<br>Odors and nuisances<br>Avian botulism; dead birds<br>Stratification in main channels |
| Monthly: | Wildlife-use observations<br>Inspection of <u>Salicornia</u> at plots<br>Salinity and water level at inlet works (for calibration of recording system)<br>General observations of circulation and turbidity |
| Annual: (or longer) | Permanent transect remeasurements<br>Re-trapping<br>Bird counts (optional)<br>Salinity and pH of the sediments<br>Water quality of discharge to Artesian Slough<br>- major ions<br>- nutrients<br>- trace elements<br>Foliar analysis of pickleweed for trace elements (if indicated) |

**TABLE 16**
**OBJECTIVES AND ELEMENTS FOR PROPOSED MONITORING**
**NEW CHICAGO MARSH RESTORATION PROGRAM**

Objectives:

1. Assess pickleweed colonization extent and quality
2. Evaluate use of restored areas by wildlife species of concern, in particular the salt marsh harvest mouse.
3. Describe the rate at which salts, nutrients and other constituents are mobilized from the sediments into the water
4. Track and respond to known potential problems such as:
   - o soil salinity and pH
   - o water salinities which deviate from the desired range of 15 to 35 ppt
   - o excessive erosion by waves
   - o algal growth requiring management
   - o potentially inadequate circulation
   - o occurrence of avian botulism
   - o others as described above
5. Document changes in the main marsh and (if constructed) in the small freshwater marsh, seasonally and over time after circulation is restored

Elements:

1. Aerial Photographs
   a. Pre-restoration and annually during initial years
   b. (optional) false-color infrared photographs
2. Permanent Transects
   a. Vegetation
   b. Live-trapping
3. Water Quality
   a. Continuous record of salinity, level, and temperatures in waters at one location near the mouth of the relict sloughs, preferably at the outlet works
   b. Regular salinity measurements at established locations; once every 2 weeks initially, then once per month. Meters to be calibrated with standards prior to each use, and records of calibration to be kept.
   c. Monthly measurement of specific conductance and temperature at locations of potential stratification.
   d. Semi-annual analyses for major ions and nutrients at outlet works
4. Sediment Quality
   a. Salinity at 0 and 15 cm at specified locations on the monitoring vegetation transects
   b. Sediment pH at pre-identified locations on transects, and in areas where colonization is not proceeding as well as elsewhere.
5. Foliar Sampling
   a. Standardized foliar sampling of <u>Salicornia</u> for copper, nickel, chromium, mercury, lead and zinc.
6. Descriptions of wildlife use of the site.
7. Routine patrolling and maintenance, daily and weekly as appropriate to detect nuisances, problems, or potential malfunctions

Where ranges or multiple frequencies are presented, we expect that monitoring will begin most frequently, and that intervals for monitoring will become longer as conditions within the marsh stabilize.

Area 14, at the northwest corner of the site and west of the SPRR tracks, will remain uninundated and will serve as a control. Soil conditions and plant vigor can be observed periodically (generally annually) for comparisons with other parts of the marsh.

5.2.2 FREQUENCY OF MONITORING, EQUILIBRATION PERIOD

During the first three years of operation, special attention is warranted to both the response of the marsh and to the effectiveness of the operations and maintenance programs. We suggest the following measures be taken to document changes, and to establish a record of operations, and to meet the design objective of responding to changes in the marsh as they occur:

1. Salinity monitoring at various locations around and within the marsh, such as those previously measured by volunteers (Appendix B) or by Harvey and Stanley Associates (1986) (daily to weekly, as needed)

2. Dissolved oxygen measurements at various locations, perhaps identical to those in 1. above (daily to weekly, as needed)

3. Profiling variations in salinity and temperature with depth at selected locations representative of areas where stratification may develop (weekly during May through October)

4. Systematic observations of the occurrence of sheens, slicks, films or other indications of petroleum distillates or naturally-occurring hydrocarbons which may affect the ecological adjustment of the restored marsh (weekly for the first 6 months, plus after first three runoff-producing storms of each winter)

5. Note all adjustments, malfunctions, changed settings, and modifications to the inlet and outlet systems (tracked daily; reported on monthly sheets)

6. Test coordination with the SJ/SCWTP during upsets or spills, by noting the elapsed time of response by marsh operations personnel, and potential changes in pH, salinity, or dissolved oxygen in the freshwater marsh, or in the Triangle Slough inlet, if affected (per-incident analysis, submitted with quarterly monitoring report)

7. Note important seasonal faunal transitions (wildlife migrations, insect hatches, feral pet usage).

We anticipate that equilibration for the restored marsh as a whole will be effectively established three to five years following initiation of circulation, although this is an estimate, and may vary with location in the marsh. The intensified monitoring program proposed for the equilibration period need not be continued beyond a time when:

1. Salinity released from storage in marsh sediments becomes small relative to salinity entering from Triangle Marsh

2. Stable pH and dissolved oxygen levels in water are observed at 90 percent of the monitoring locations

3. Operation of the salinity and water-level controls maintains these parameters within specified ranges for one year.

The intensified equilibration period monitoring may be discontinued after three years, even if the conditions outlined above are not met, provided that all quarterly reports have been filed and corrective actions recommended in the reports have been authorized or implemented.

5.2.3 FREQUENCY OF REPORTING

During the equilibration period following introduction of water from Triangle Marsh, monitoring results should be reported quarterly, by the seventh day of March, June, September and December.

Once water levels, salinities, and turbidities (adjusted for season) appear to be stable, or after three years, annual reporting should be commenced. Annual reports are to be filed by September 7 of each year.

Reports should include the elements and measurements presented above. Upsets or other events or conditions affecting water levels, salinity, or wildlife use of the marsh should also be recorded. The response of the marsh operators to deviations from the anticipated conditions or to upsets and events should be noted in the reports, and evaluated, as the primary objective of the monitoring program at New Chicago Marsh is to promote actions to sustain desired conditions. Cumulative inflows and outflows of water and total dissolved solids should be reported by month or season.

In light of the complexity of marsh restoration, reports and evaluation should be prepared by individuals with diverse technical backgrounds. Where certifications and/or registration of professionals are required by California law, individuals possessing such certificates or registrations should be responsible for related sections of the report and for review of the suitability of response.

# 6 CONCLUSIONS

1. Restoration of the 340-acre New Chicago Marsh can augment the quality and extent of habitat available near Alviso for the salt marsh harvest mouse, a federal- and state-listed endangered species. The marsh, presently diked and isolated from tidal action for more than 100 years, is expected to support more of the semi-continuous pickleweed habitat preferred by the salt marsh harvest mouse if brackish waters with moderate circulation are allowed to partly inundate the relict tidal network of channels and flats.

2. The approaches available for restoring New Chicago Marsh differ substantially from those used in other diked wetlands surrounding San Francisco Bay because of three primary factors:

   a. Presence of the endangered salt marsh harvest mouse, and the real potential for habitat enhancement and extension to the full area of New Chicago Marsh

   b. Location of the marsh within the cone of land subsidence centered upon San Jose, induced by heavy ground-water extraction during the 1940s and 1950s; the mean elevation of the marsh, at approximately -3.0 feet below mean sea level, precludes restoring tidal circulation without regularly flooding the critical habitat areas

   c. Salinity of the sloughs and southern San Francisco Bay near the marsh is severely depressed by large discharges of treated effluent from the San Jose/Santa Clara Wastewater Treatment Plant into Artesian Slough, near the southeastern corner of the marsh; nutrient levels and concentrations of many trace elements are elevated in the effluent.

3. We believe that salinities suitable for enhancing pickleweed growth, thought to be about 15 to 35 parts per thousand (ppt), can be obtained at the crucial times of year by a combination of drawing water from the most saline of the nearby sloughs (at Triangle Marsh), and concentrating the water by evaporation in New Chicago marsh. One bank of three pumps will be operated to circulate the water within the marsh, and to release some of the water through the levees back into the sloughs.

4. Water levels in the marsh most months of the year must be maintained at a steady level, within narrow tolerances, as a means of mosquito control. The

steady levels will also serve to discourage predation by feral dogs and cats as large areas of the slough will be isolated by internal sloughs and open water.

5. Circulation within the marsh should be promoted by constructing substantial cross-connections between the sloughs, primarily along the southern edge of the marsh, which (prior to subsidence) used to be the headwaters of several internal slough systems.

6. Maintaining water levels and salinities within specified ranges plus sustaining internal circulation will require a real-time monitoring system capable of integrating information collected at the outlet/recirculation pumps and at the intake, 1.5 miles to the northwest. We have proposed a system of telemetric controls capable of sensing salinity and water levels, and suited for operation using a standard personal computer. The sensors may be queried from this computer, which can be located either at SFBNWR headquarters in Newark or at the existing Environmental Education Center at New Chicago Marsh.

7. An initial equilibration period of perhaps three to five years is expected before soil salinities and the internal drainage net have assumed levels adjusted to the new hydrologic regime. Intensified monitoring is proposed for this period.

8. Careful and sustained monitoring will be necessary to refine the water management program as the project matures. This hydrologic regime has not been used before. It may represent one of the most-intensive management programs proposed for restoration of diked wetlands. As suggested by our consultant, Bill Nuttle, "... a gradual interactive process of hydrological modification, monitoring, evaluation, and planning subsequent modification is necessary" to achieve the desired goals.

   Accordingly, a committed monitoring-and-response program similar to that described in Chapter 5 should be implemented to:

   a. Make the adjustments needed to maintain salinities and water levels within the desired tolerances

   b. Expeditiously address nuisances, algae or sediment accumulation, or other management problems which may develop during the initial equilibration period

c. Systematically track wildlife use, vegetation, water quality, and sediment quality to establish that desired functions and values are being supported by the restoration regimen.

9. The restoration program, sponsored and facilitated by the Peninsula Open Space Trust, will be carried out by the San Francisco Bay National Wildlife Refuge, a unit of the U.S. Fish and Wildlife Service.

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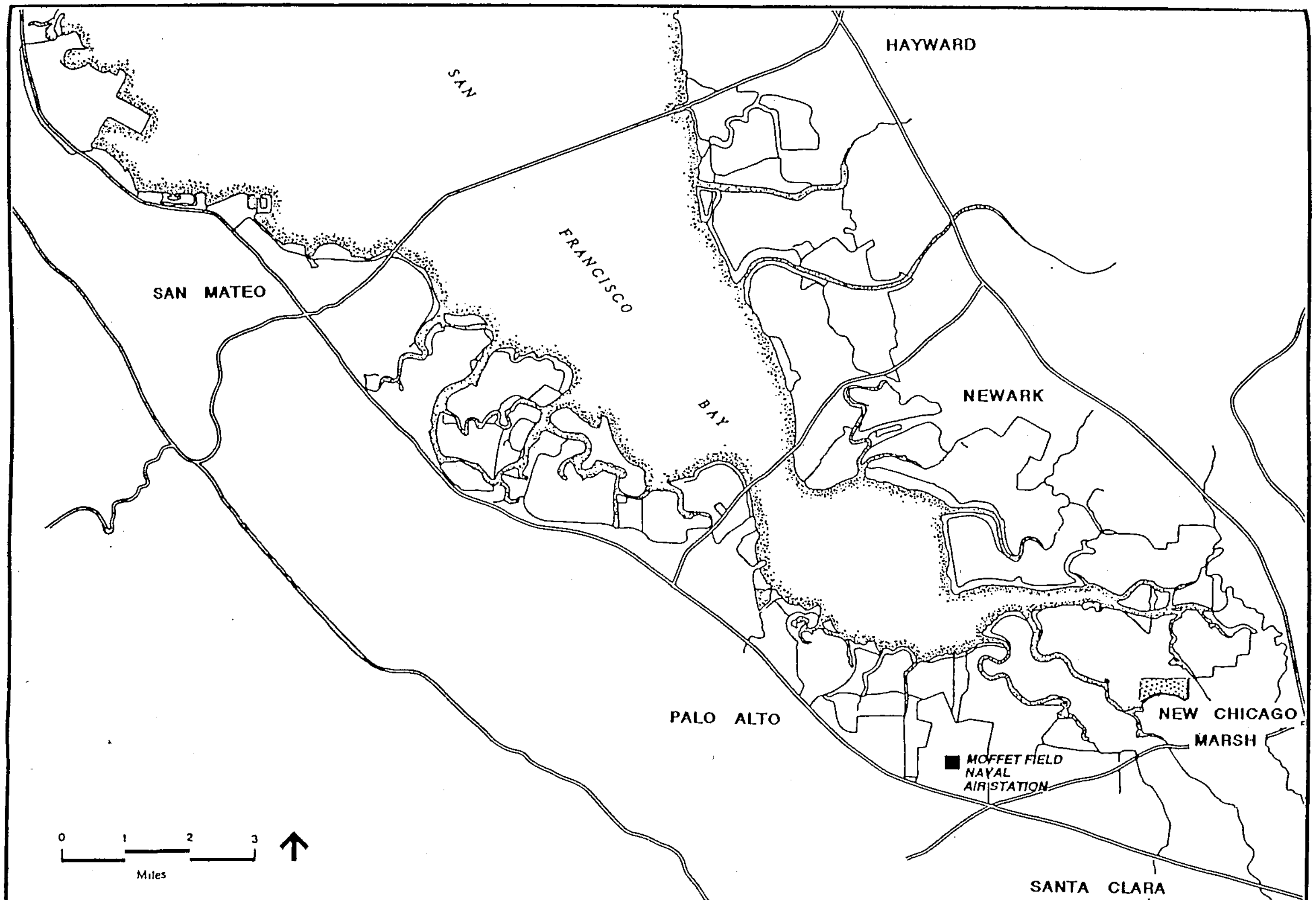
# PLATES




Basemap: San Francisco Bay Conservation and Development Commission, 1988

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Plate 1. Regional Location Map of New Chicago Marsh, Alviso, California

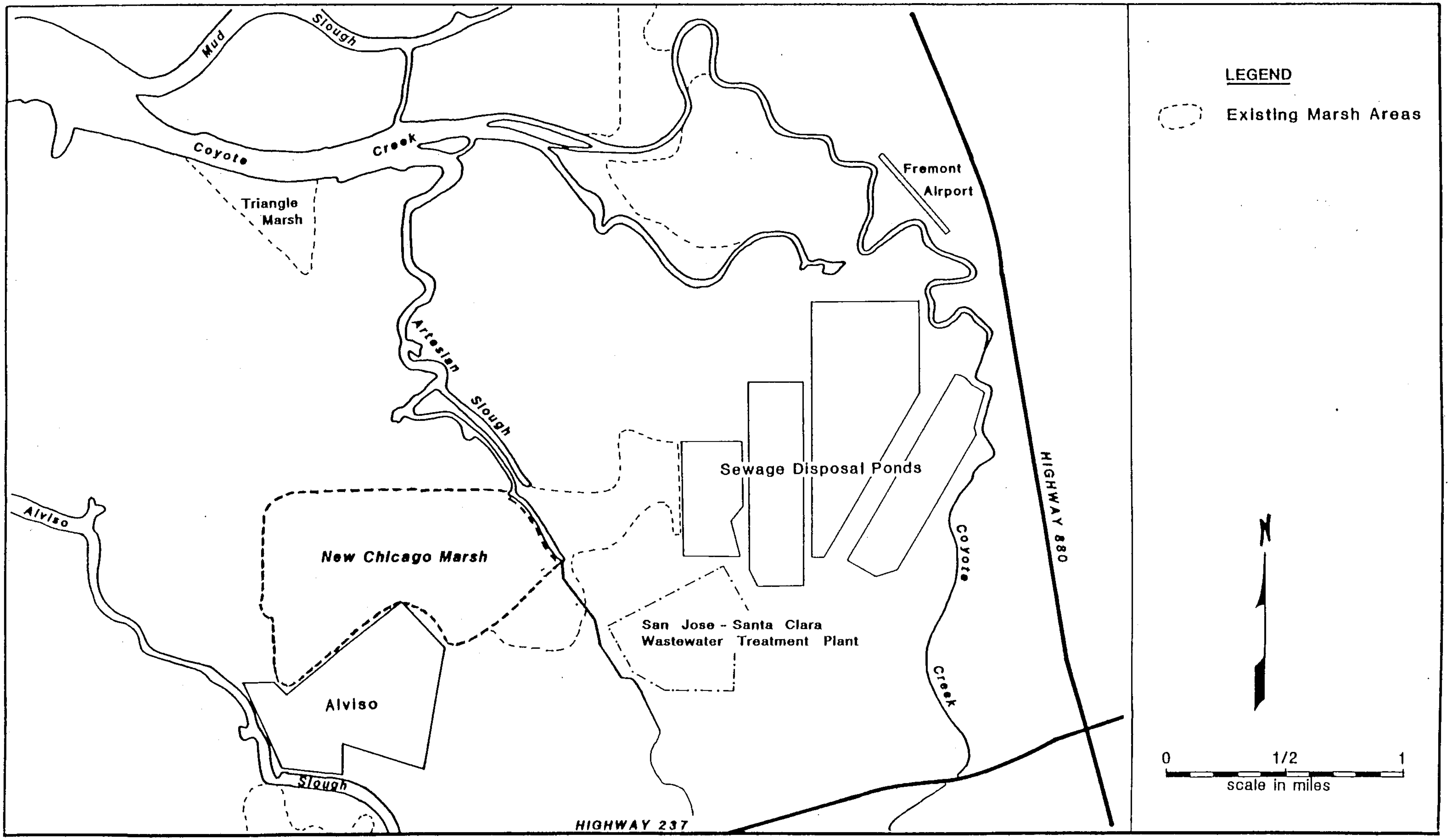


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**Plate 2. Location Map**
New Chicago Marsh, Alviso, California

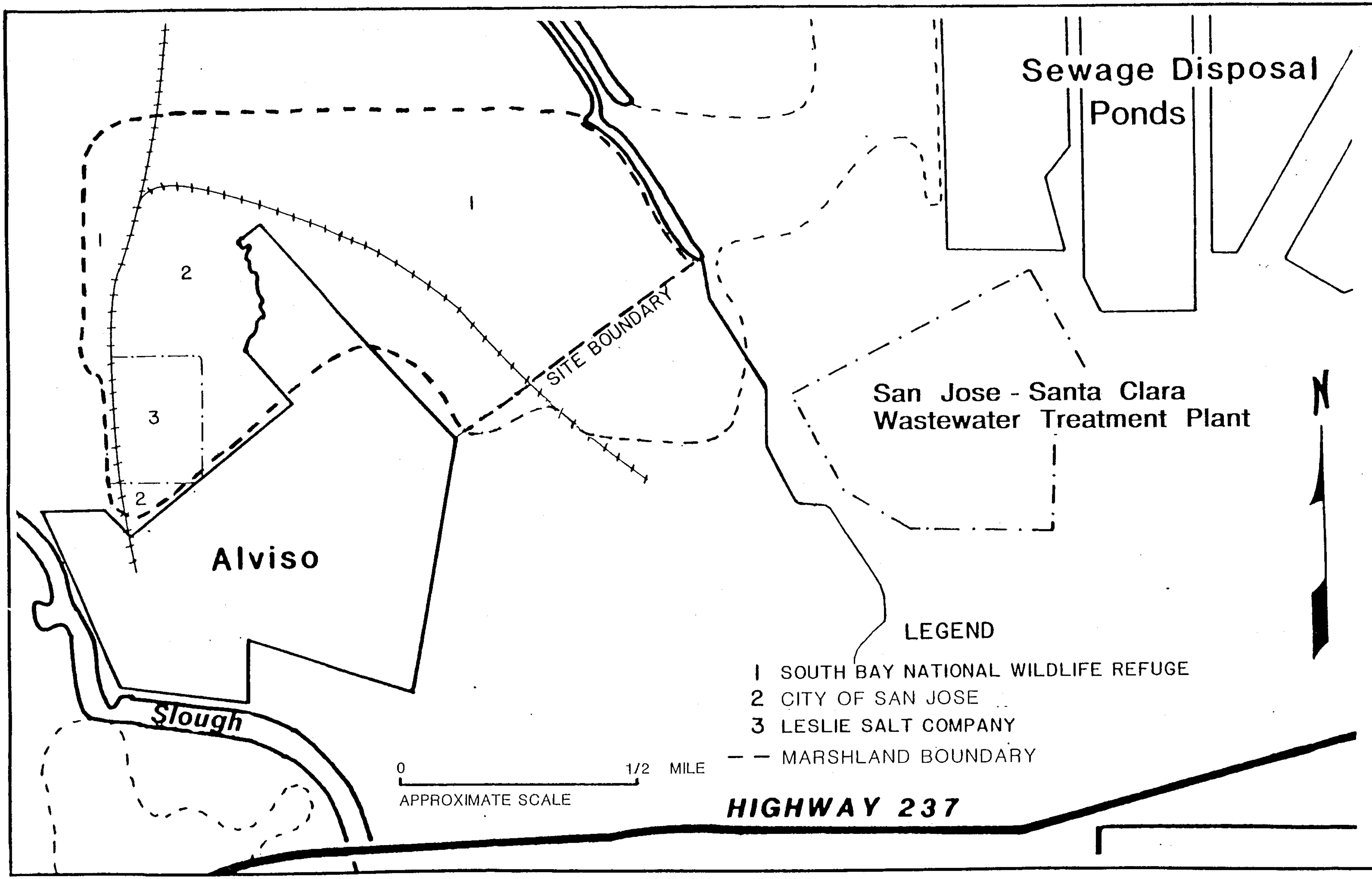


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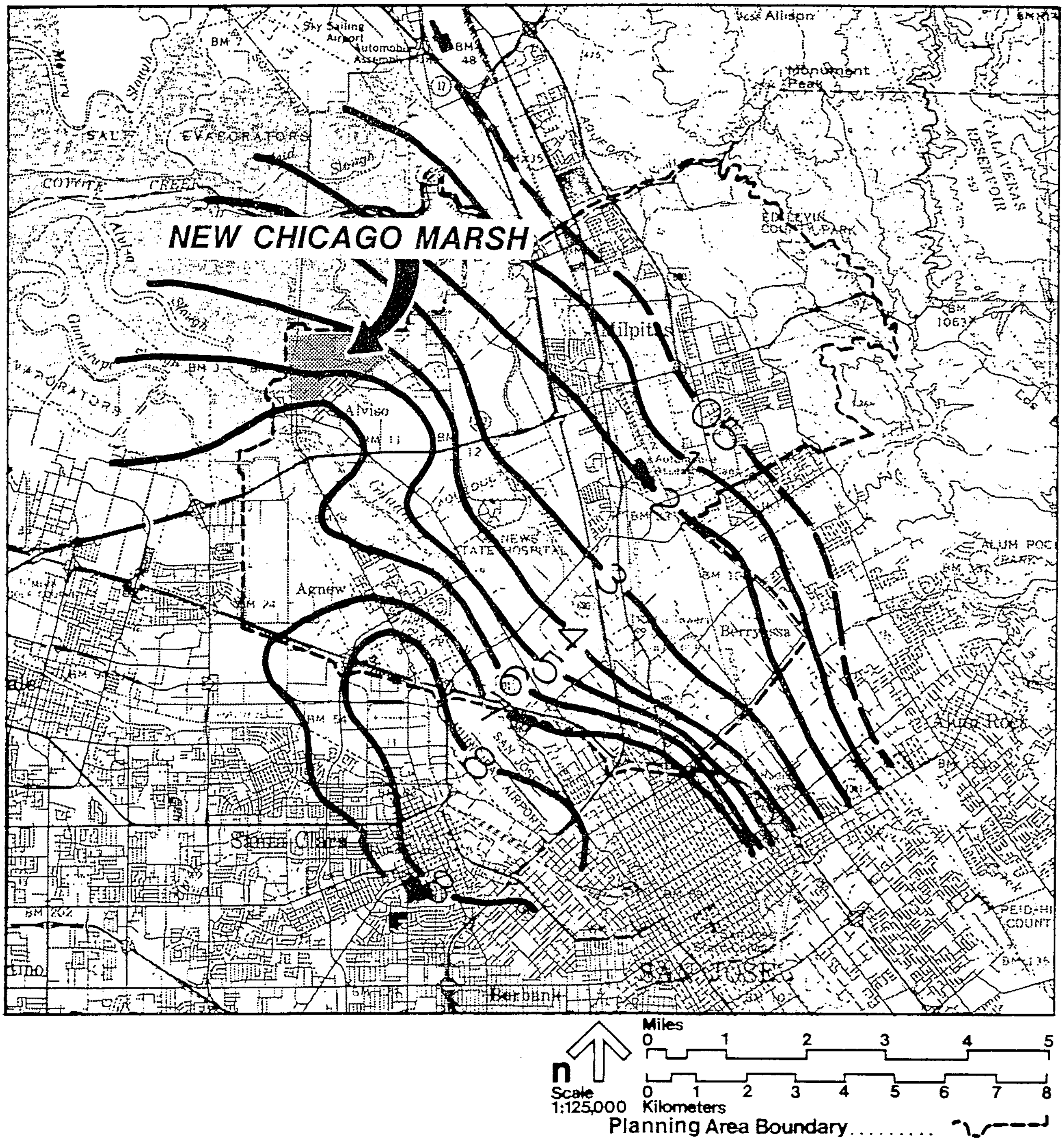
**Plate 3. Land Ownership**
New Chicago Marsh, Alviso, California




Subsidence, in feet, 1934 to 1967; subsidence since 1967 has been negligible.

Source: EDAW, 1978, based on California DRW Bulletin 118-1 and several published and unpublished studies by J. F. Poland.

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Plate 4. **Historical Subsidence Due To Ground Water Overdraft**
New Chicago Marsh, Alviso, California

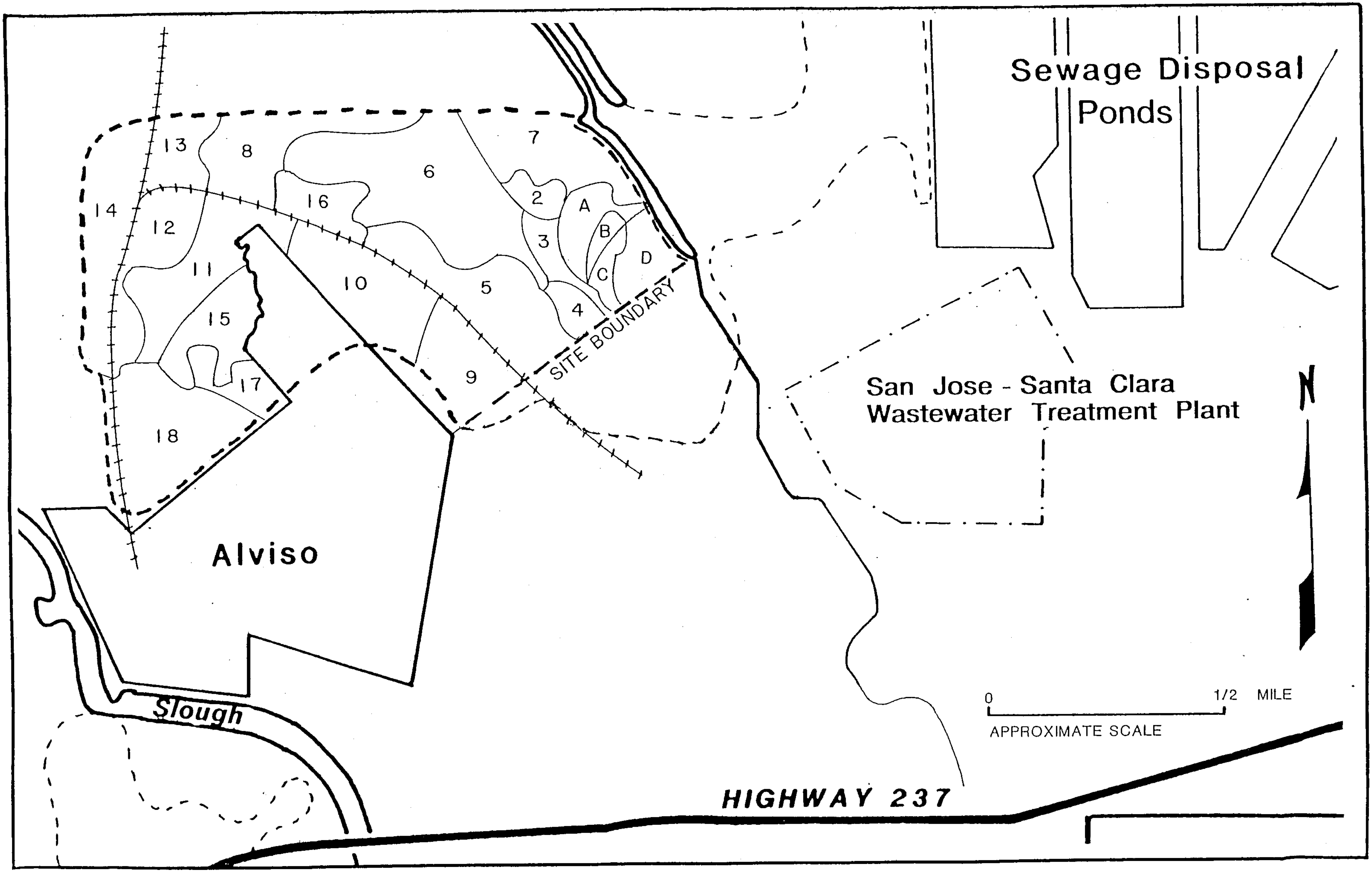


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**Plate 5.** **Capacity Curve Subdivisions**
New Chicago Marsh, Alviso, California

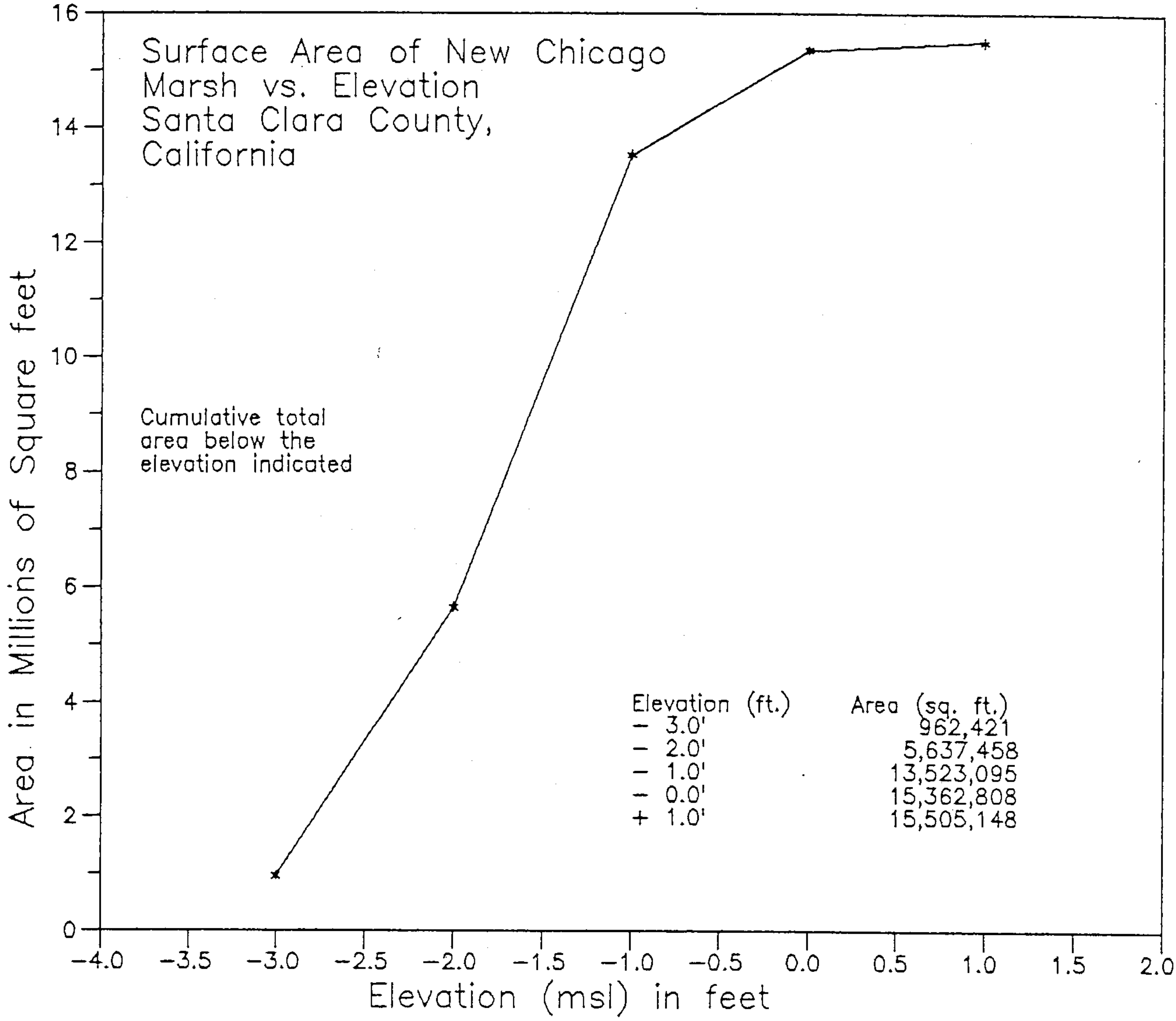


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**Plate 6.** **Hypsometric Curve - Surface Area**
New Chicago Marsh, Alviso, California

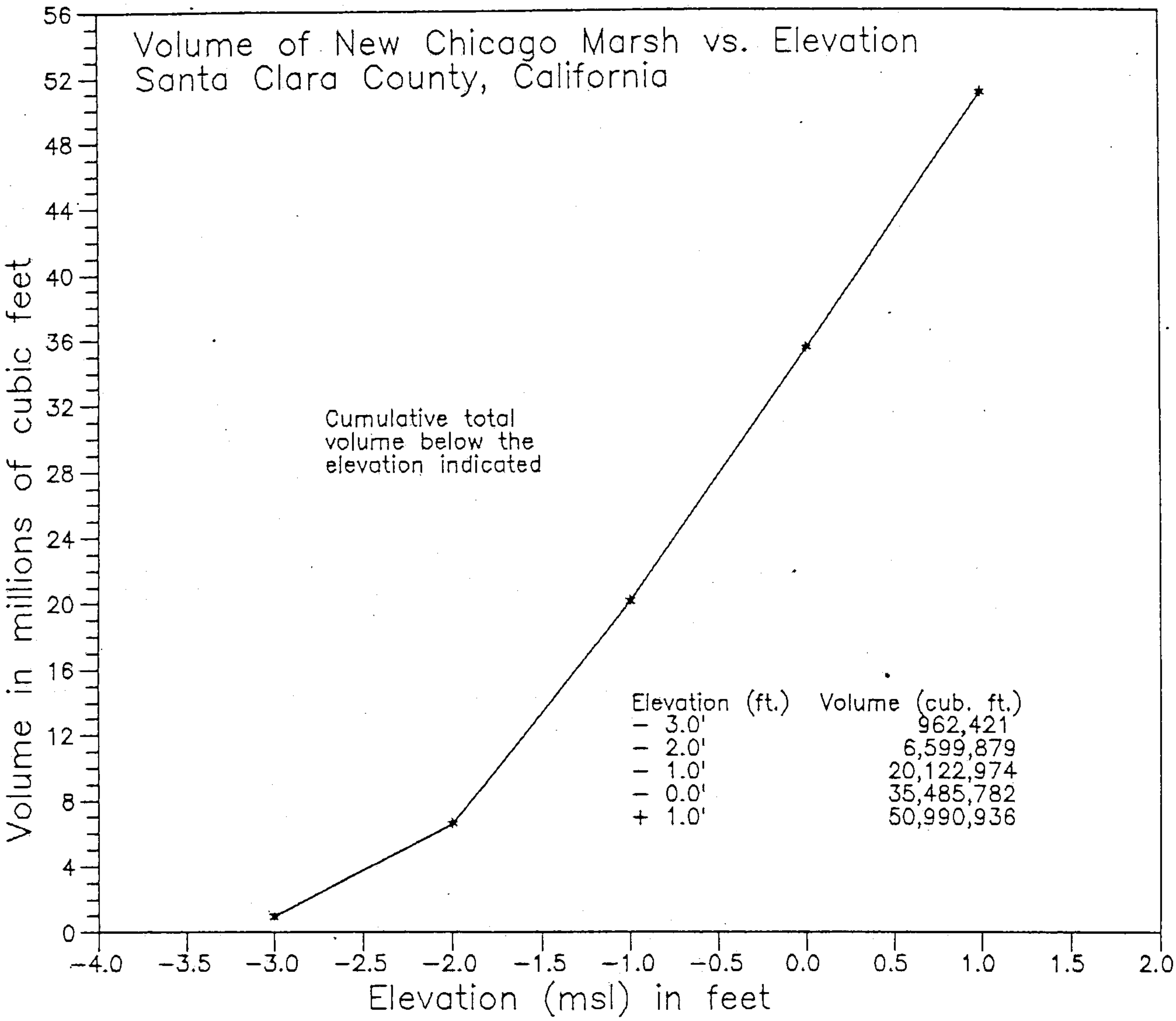


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**Plate 7.** **Hypsometric Curve - Volume**
New Chicago Marsh, Alviso, California

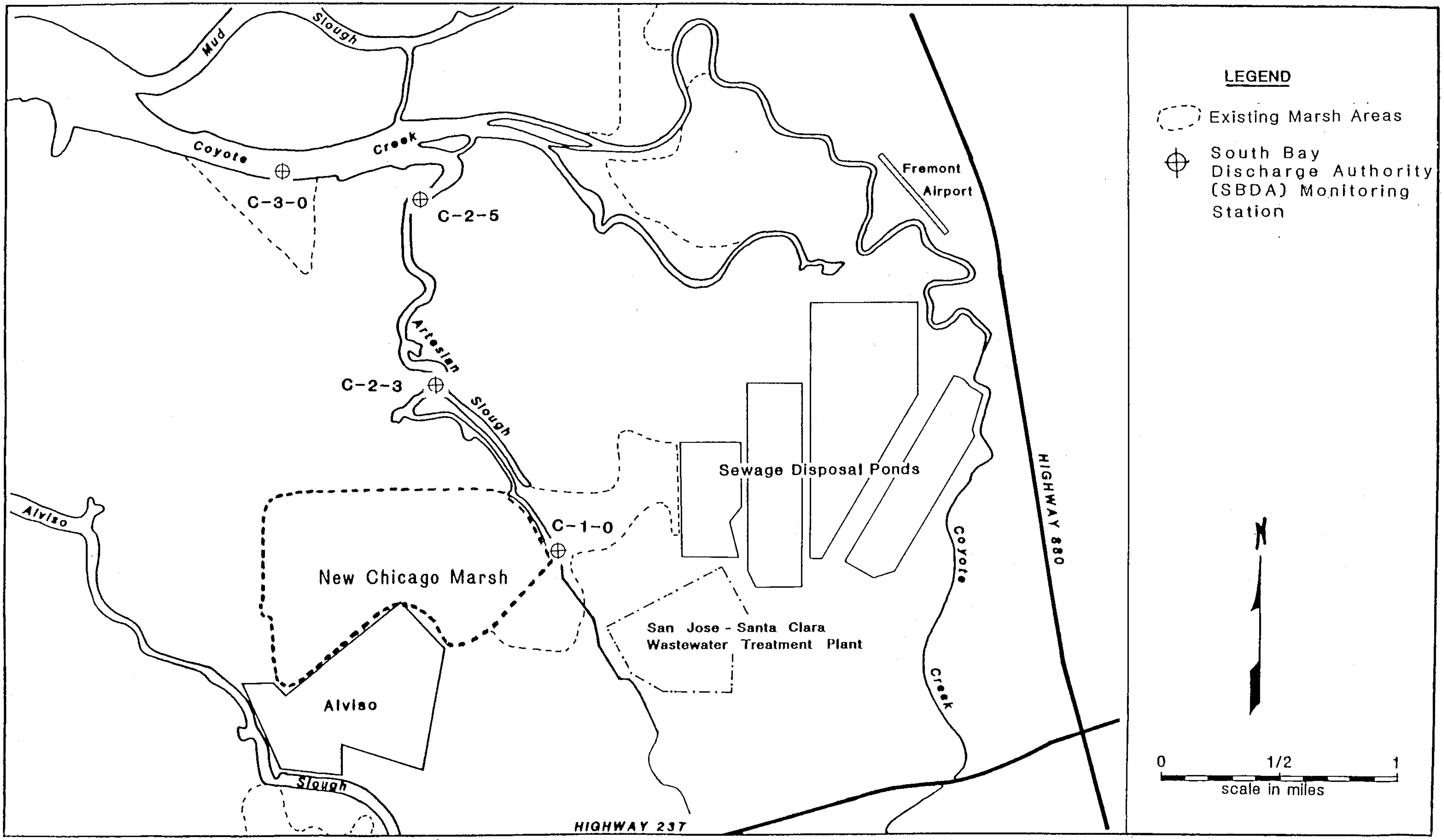


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Plate 8. SBDA Monitoring Locations Near New Chicago Marsh, Alviso, California

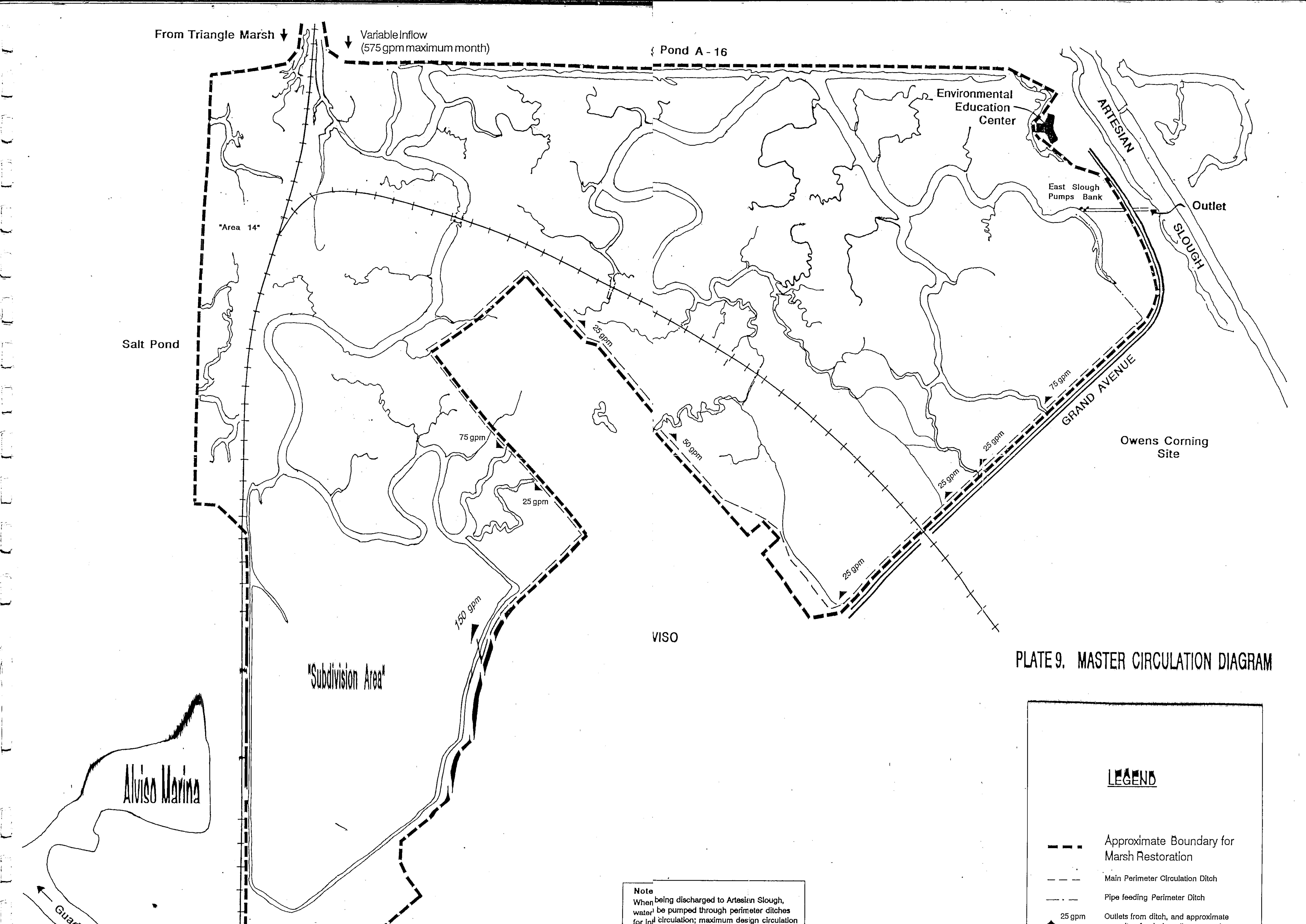



PLATE 9. MASTER CIRCULATION DIAGRAM

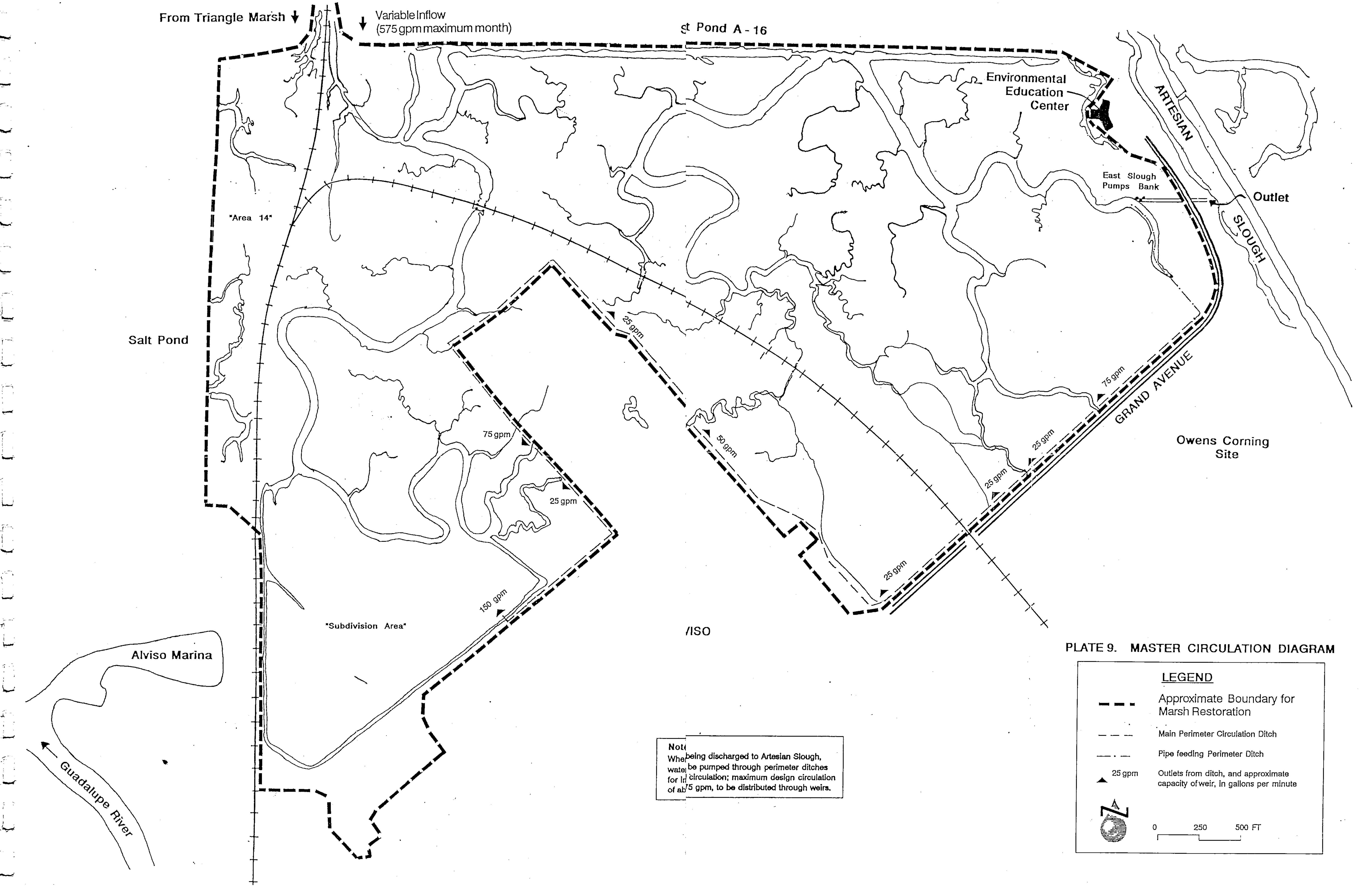
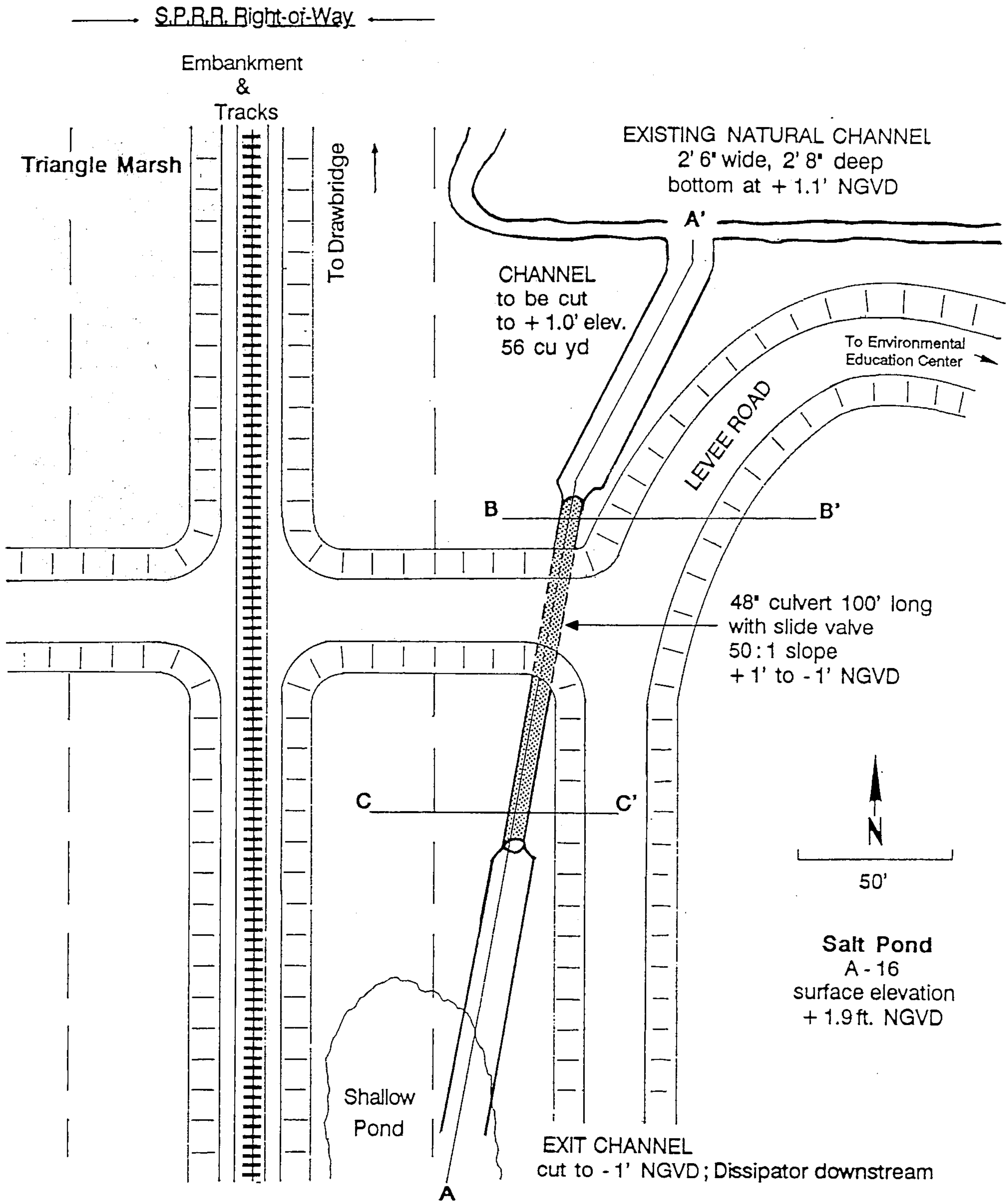
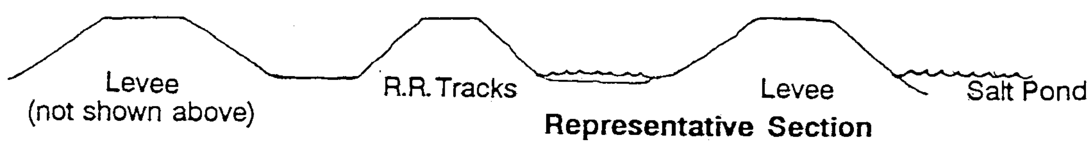



PLATE 9. MASTER CIRCULATION DIAGRAM




**Representative Section**

Drawing developed by John Wade

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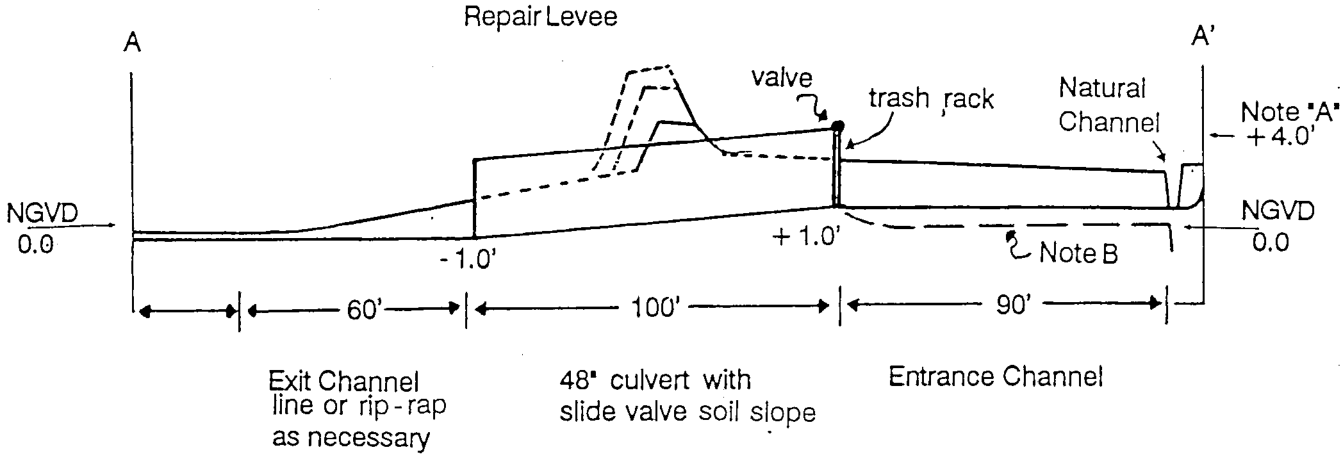
Plate 10. Plan View of Inlet Area Near Triangle Marsh, New Chicago Marsh, Alviso, California

## CHANNEL PROFILE

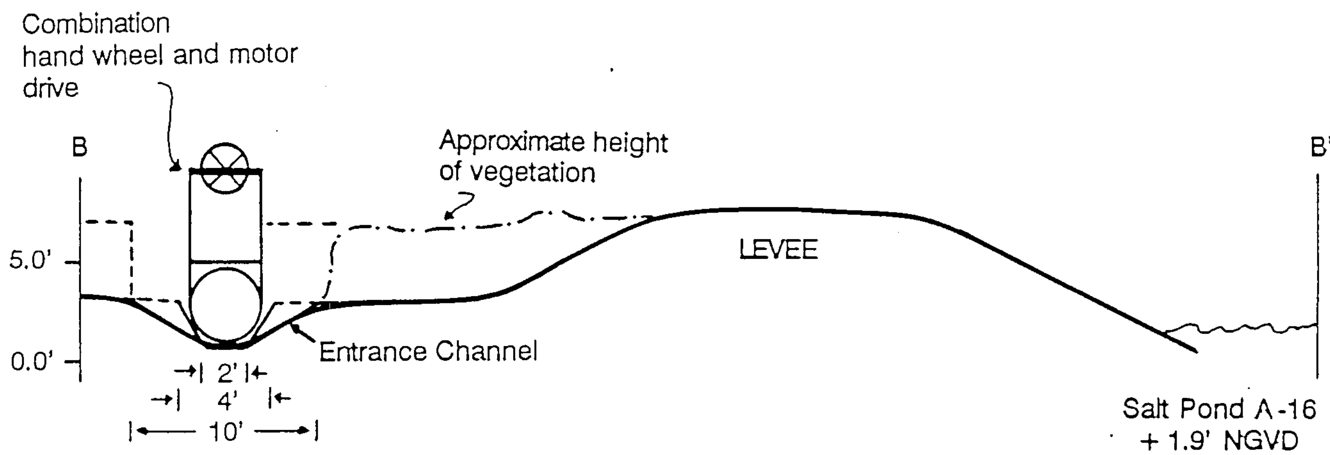



Notes

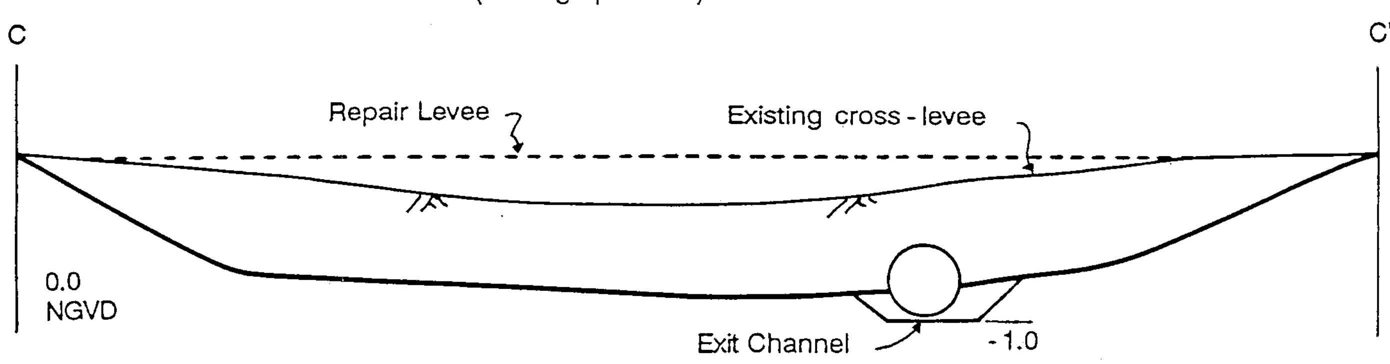
A: A high tide of + 6.2 MLLW, at the Golden Gate reaches approximately + 4.0 NGVD here.

B: Clear vegetation within main channel and excavate to + 0.0 NGVD.

## ENTRANCE CROSS SECTION




## EXIT CHANNEL AND CROSS-LEVEE SECTIONS
(looking upstream)




Sections and measurements by John Wade

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Plate 11. Preliminary Conceptual Section of Triangle Marsh Inlet New Chicago Marsh Restoration, Alviso, California

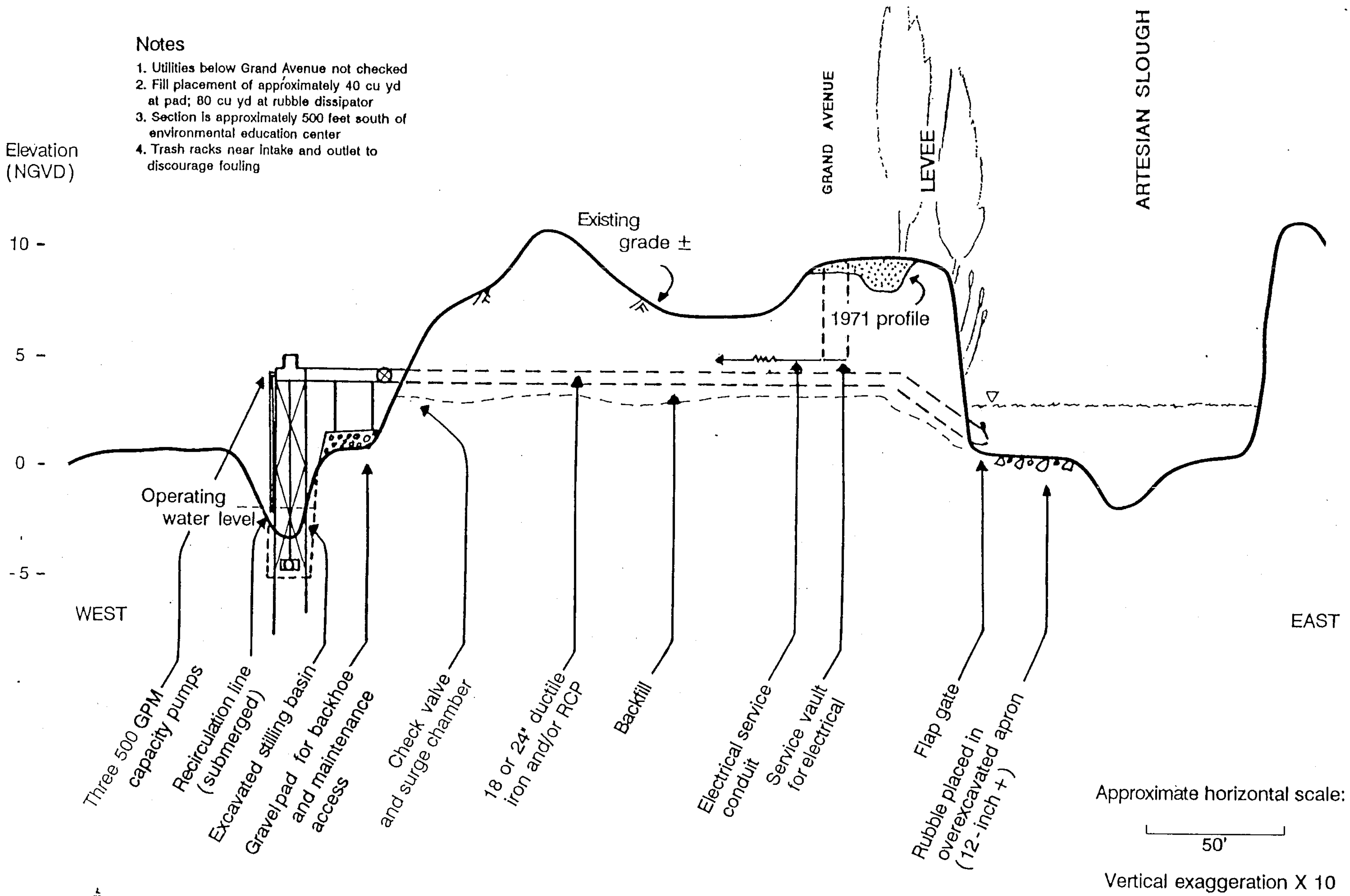


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Plate 12. Conceptual Section of East Slough Discharge, New Chicago Marsh Restoration
Alviso, California

# APPENDIX A

## NUTTLE REPORT OF JUNE 1986

# IMPROVEMENTS TO THE HYDROLOGY OF NEW CHICAGO MARSH,

# SANTA CLARA COUNTY, CALIFORNIA

William K. Nuttle PhD

Massachusetts Institute of Technology

June 1986

## INTRODUCTION

The New Chicago marsh is a 200 acre salt marsh near Alviso, Santa Clara County, California. The marsh has been diked and the area has subsided so that the elevation of the marsh is now between 3 and 5 feet below sea level. The area remains vegetated by pickleweed, the dominant salt marsh vegetation in the San Francisco Bay area; however the vegetation is generally degraded relative to undisturbed marshes.

It has been proposed that water be introduced into the New Chicago marsh from Artesia Slough to improve conditions in the marsh in general and to enhance the habitat of the Salt Marsh Harvest Mouse in particular. The purpose of this report is to provide background and guidance for designing a plan to manage the hydrologic regime of the marsh. Existing conditions in New Chicago marsh are reviewed, and soil and water quality parameters are identified that bear directly on the current conditions in the marsh. Specific recommendations are made for improving the hydrologic regime, and a program is outlined to monitor the progress of changes in the soil and water quality parameters and in the quality of the ecosystem in response to changes in the hydrology.

This report has been prepared for J.H. Kleinfelder and Associates as part of their study of the feasibility of hydrologic improvements in the New Chicago marsh. The report reflects the current state of knowledge regarding the role of hydrology in the salt marsh ecosystem. Data relating specifically to conditions in New Chicago marsh were taken from a report prepared earlier this year by Harvey and Stanley Associates (Harvey et al 1986) and from personal communication with H.T. Harvey, Harvey and Stanley Associates, and B. Hecht, J.H. Kleinfelder and Associates. Information from the current scientific literature has been included when appropriate.

## PRESENT CONDITIONS IN NEW CHICAGO MARSH

New Chicago marsh is diked and is no longer in direct contact with the tidal waters of South San Francisco Bay. Water enters the marsh as direct precipitation and runoff from adjacent upland areas. The marsh serves as a flood basin for San Jose, Alviso and Highway 237. It is not known how important runoff into the marsh is relative to direct precipitation under routine conditions. The marsh is underlain by clay, so an appreciable inflow of water from the regional groundwater system is not expected. Water is removed from the marsh principally by evapotranspiration. Potential evapotranspiration exceeds yearly precipitation by a factor of three (48.3 inches versus 13.1 inches), and the imbalance is worst during the period May - September when potential evapotranspiration is highest and rainfall is least. Drainage can occur into Artesia Slough from the marsh through ten 48" diameter pipes during times of high water levels in the marsh. The bottoms of the pipes are set at -1 ft. MSL and flapper valves prevent the inflow of water during high tides. Normal water levels in the marsh are at -5 ft MSL.

The vegetation in the marsh is predominately pickleweed (Salicornia pacifica). There are small amounts of salt grass (Distichlis spicata) and alkali heath (Frankenia grandifolia). Twenty percent of the area is unvegetated. Shallow ponds, rain-fed in the winter, cover 20 acres, 10 percent of the area of the marsh.

The marsh sediment is a silty clay. pH is low, <5 in some areas, and the salinity of the pore water is high, generally greater than sea water. Salinity and pH vary with distance from the creek in creek bank regions, In two transects of soil samples perpendicular to a creek bank pH decreased away from the creek in both cases and salinity increased away from the creek in one. There was no consistent variation of salinity with distance from the creek in the other (Harvey et al 1986). The soil salinities of unvegetated acres in the marsh are generally higher than the salinities in vegetated areas. It is probable that very high salinities (>100 ppt) occur at the sediment surface in unvegetated areas of the marsh during the summer months.

The salinity of the surface water in the marsh is highly variable from season to season and with location in the marsh. Observed values range from 2 ppt to 105 ppt (Harvey et al 1986). Zetterquist (1977) reports salinities in New Chicago marsh in excess of 220 ppt.

## CRITICAL SOIL AND WATER QUALITY PARAMETERS

The distribution of different species of vegetation within an undisturbed marsh is controlled by the differences that occur in salinity and the degree of aeration of the sediment as one proceeds landward from open water through a marsh. On the west coast of the United States a sharp boundary separates the two dominant species of vegetation at about the location of mean high water (Hinde 1954, Mahall and Park 1976). Cord grass (Spartina) dominates below the level of mean high water down to the level of mean low water, and pickleweed is predominant above the level of mean high water up to the edge of the marsh, where terrestrial species take over. The conditions imposed by frequent inundation; soil salinities near surface water concentrations (sea water salinities or less), constant water saturation of the soil and consequent anoxia of the pore water, favor cord grass over pickleweed. Cord grass develops internal gas spaces that provide a pathway for the transport of oxygen in the plant to compensate for the lack of oxygen in the sediment. Pickleweed has the same structural adaptation to saturated conditions in the sediment, but to a lesser extent. Pickleweed is able to grow in conditions of occasional flooding but requires a higher degree of aeration of the sediment than daily flooding allows. This restricts pickleweed to the area of the marsh above mean high tides.

A long term balance is maintained between fluxes of salt into and out of the sediment of a marsh. Salts are carried into the sediment by infiltration when the marsh is flooded by tides. Water is lost by evapotranspiration and the salinity of the water remaining in the sediment increases. Some salt is removed by the vegetation, but this amount is small relative to the total flux of water and salt in the sediment (Mahall and Park 1977). The drainage of infiltrated water through the sediment and into the creeks does not occur at a rate sufficient to be important to the salt balance (Nuttle 1986). The principal efflux of salt seems to occur in conjunction with flooding by tides, but the transport mechanism is not known. It is reasonable to assume that some diffusive-type process is involved, so the rate of salt removal from the sediment by flooding would be roughly proportional to the product of the frequency of surface flooding and the difference between the concentrations of salt in the pore water and in the flooding water. This leads to lower salinities in the sediment in the area of the marsh that is frequently flooded and higher salinities in the less frequently flooded areas, the areas above the level of mean high water. The higher salinities limit the distribution of cord grass at its upper boundary and pickleweed is able to predominate.

The ability of pickleweed to grow in saline soils gives it an advantage over terrestrial species in the interval between mean high water and extreme high water. Above extreme high water, soil salinities are low and terrestrial plants prevail over marsh species. Other species of marsh plants inhabit the region between mean high water and extreme high water, but pickleweed seems to have the advantage by its ability to tolerate high salinities and low moisture contents that can develop in the sediment of San Francisco Bay marshes during the summer and early autumn.

The present conditions in New Chicago marsh are consistent with the picture presented above, extrapolated to the situation in which tidal flooding of the marsh surface has been eliminated. Cord grass is not found in appreciable quantities (Harvey et al 1986) and high salinities in the sediment have probably prevented the invasion of terrestrial species. Pickleweed is found throughout the marsh, but there are indications that it is significantly stressed by the present conditions. Twenty percent of the marsh is unvegetated and sparse cover is observed in a large portion of the vegetated area. The average height of the pickleweed is less than that found in undisturbed marshes (33.2 cm versus 50 cm).

The vegetation in New Chicago marsh survives on much less moisture than would be available in an undisturbed marsh under the same climatic conditions by virtue of the occasional flooding of the surface by the highest spring tides. Pickleweed is efficient in its use of water (Mahall and Park 1977), and this probably contributes to its survival under reduced moisture conditions. The effects of low soil moisture of pickleweed have not been studied, because moisture availability is not normally an issue for wetland vegetation. It is likely that soil moisture is a factor in seed germination in the spring and that low soil moisture in the summer causes reduced growth. Extremely high salinities have similar effects (Ustin et al 1982). It is not possible to separate the effect of low moisture content from the effect of extremely high salinity because high pore water salinities are a consequence of low water content in the sediment.

Elimination of tidal flooding in New Chicago marsh has increased the aeration of the sediment. Low moisture contents and the corresponding fall in the water table below its natural position near the sediment surface have led to the oxidation of formally anoxic regions of the sediment. Sulfides, which accumulate naturally ~~is~~ in salt marsh sediments as a consequence of anaerobic, processes, are being oxidized to form sulfuric acid. Normal pH in salt marsh sediments is in the range 5-6; pH values below 5 observed in New Chicago marsh indicate the formation of sulfuric acid. The observation of generally lower pH ~~is~~ in the sediment at greater distances from a ~~creek~~ channel (Harvey et al 1986) is consistent with the effects of poor horizontal drainage in the sediment discussed above.

Reduced productivity of the vegetation in New Chicago marsh has consequences for the structure of the sediment that may affect the degree of aeration of the sediment if changes in hydrology return normal moisture conditions to the marsh. Under natural conditions the aeration of nearly saturated sediment is enhanced by the presence of macropores in the root zone (Chen 1986). These very large pores are the result of the activities of burrowing animals and dead and decaying roots, and are therefore related to the health and productivity of the vegetation. No information is available about the presence or absence of large pores in the sediment in New Chicago marsh, but it is to be expected that they are no longer present in the unvegetated areas.

There is evidence that the internal sloughs become stratified with fresher water from recent rainfall overlying a layer in which the salinity has been elevated by evaporation. Stratification prevents full mixing from occurring in the sloughs, which can result in low oxygen content and high temperatures in the saline layer. High temperatures can develop when stratification prevents convective transport of heat that enters the water as solar radiation. The situation presents a hazard to the fish in the sloughs and limits their range of activity in the marsh. The fish living in the marsh help to control mosquito production and are a source of food to wading birds. In the absence of tidal inundation of the marsh surface the water quality in the ponds and internal sloughs does not have a large effect on the vegetation.

Summary:

Conditions observed in New Chicago marsh are consistent with changes expected with respect to natural conditions as the result of eliminating tidal flooding; evaporative concentration of salts, low moisture contents and increased aeration of the sediment. High salinities and low moisture conditions probably are the critical factors controlling the present state of the vegetation in New Chicago marsh. Salinity induced stratification and consequent low oxygen content and high temperature of the stagnant bottom water is a possible hazard to the fish population in the marsh.

## RECOMMENDED CHANGES TO THE HYDROLOGY OF NEW CHICAGO MARSH

The objectives for the restoration of New Chicago marsh are to improve the habitat for the Salt Marsh Harvest Mouse (Reithrodontomys raviventris raviventris) and to improve the marsh functions in general. Improvement of the Harvest Mouse habitat amounts to increasing the density and extent of pickleweed cover while maintaining saline conditions in the marsh (Zetterquist 1977). High salinities and low moisture availability probably are the critical factors controlling the present state of the vegetation in New Chicago marsh. It is proposed that changes be made in the present hydrologic regime of the marsh as a means of pursuing the objectives of restoration. Specifically, the following actions are recommended:

1) Resume flooding of the marsh surface.
2) Improve mixing in the ponds and sloughs.
3) Reclaim unvegetated areas.
4) Implement improvements incrementally and in concert with a program of monitoring.

### 1) Resume flooding of the marsh surface.

Major fluxes in the moisture and solute balance of salt marsh sediments are related to tidal flooding of the marsh surface. Resumption of surface flooding in New Chicago marsh is the single most effective action that can be taken to improve conditions in the marsh. The greatest benefits of resumed flooding will be realized during spring and early summer when moderate salinity and an adequate supply of moisture are required for seed germination and plant growth.

Reproduction by seeding is an important mechanism for the reestablishment of pickleweed in unvegetated areas (Purer 1942, Faber 1983). It is suggested that the frequency of flooding during the spring and summer follow the natural pattern of flooding for areas of a marsh located above mean high water, i.e. one or two periods of flooding per month coincident with the highest spring tides. Each period of flooding should consist of three consecutive days during which the surface is flooded for a period of two to three hours. The first day of flooding serves the purpose of recharging the soil moisture while subsequent days of flooding provide for transport of accumulated salts out of the sediment.

The transport of salt out of the sediment during flooding is probably improved by having a significant depth of water (>10 cm) standing on the surface rather than providing just enough water to wet the sediment. Surface flooding of excessive depth or duration may have adverse effects on pickleweed that are independent of the effects of reduced aeration (Mahall and Park 1976). Periods of flooding should be limited to a few hours duration and depths to less that the mean height of the vegetation.

The salinity of the flood water should be maintained in the range 20-30 ppt to maintain sediment salinities at values slightly higher than seawater salinities over the long term. Fresh water from Artesia Slough can be applied directly to speed the reduction of sediment salinities initially. Continued flooding with fresh water and leaching of salt out of the sediment will have one of two adverse consequences. Either the reduction in salinity of the pore water will so change the structure of the sediment (by dispersing the clay fraction) that the sediment becomes unable to support vegetation, or freshening conditions will result in a succession from salt marsh vegetation to freshwater wetland vegetation. The salinity of the flood water can be maintained by recirculating the surface water within the marsh, removing saline water and adding fresh water as necessary.

2) Improve mixing in the ponds and sloughs.

Periodic flooding of the marsh surface will result in some improvement in mixing in the drainage network of the marsh. If stratified conditions occur and are considered to be a significant hazard than additional measures should be taken to improve mixing. The main sloughs should be deepened as necessary so that, in the case that stratification develops, the saline bottom water will collect at one or two locations where it can be detected. Mixed conditions can be imposed by mechanical means or the stagnant bottom water can be drawn off and discharged from the marsh by pumping. Improved mixing in the drainage network without surface flooding will result in improved conditions in the marsh, but there will be no improvement in the vegetation over most of the marsh.

3) Reclaim unvegetated areas.

Revegetation of unvegetated areas will occur by natural processes following the resumption of surface flooding. However, the process will be slow (2-3 years, Faber 1983) as a result of the presently high salinities in the sediment and the absence of macropores, which are necessary for optimal aeration of the sediment. The lack of macropores may also retard the transport of salt out of the sediment thus prolonging the period of time until salinities have been reduced enough to allow revegetation. The rate of revegetation may be increased if the improvement of soil conditions is actively pursued by tilling the sediment and by flooding these areas more frequently to increase the rate of salt removal. Mechanical disturbance of the sediment will increase the number of large pores and will facilitate the transport of salt out of the sediment during periods of flooding. A 10 cm depth of disturbance is suggested based on the rooting depth of pickleweed and the general observation that extreme salinities in salt marsh sediments are found in the upper 5-10 cm.

4) Implement improvements incrementally and in concert with a program of monitoring.

There is no precedent for the degree to which the hydrology must be artificially controlled in the restoration of New Chicago marsh. The recommended frequency, duration and depth of surface flooding are based on the premise that the managed hydrologic conditions must approximate conditions in an undisturbed marsh to provide optimal conditions for the vegetation. It is possible that the management objectives can be met more efficiently with another hydrologic regime. The final recommendation is that modifications to the hydrology of New Chicago marsh be made incrementally so that an efficient plan for the management of the hydrology evolves based on the observed response of the ecosystem to changes in hydrology.

The first step should be to implement one or all of the above recommendations in a relatively small area of the marsh that encompasses conditions of interest throughout the marsh. Concurrently, a monitoring program should be established to document the response of the ecosystem to changes in hydrology. These results should be assessed along with the costs of construction and operation of the hydrologic modifications to plan for the next step in the process, which may be either a modification of the management practices at the initial site or an expansion of the area affected by hydrologic management. The requirements of the monitoring program are outlined in the next section.

The rate of progress of the restoration of New Chicago marsh is limited by the response of the ecosystem. The vegetation in the marsh follows a yearly cycle of seeding and new growth in the spring and early summer followed by senescence in the autumn and winter. The effects of a management program initiated before the spring growth in a vegetated area of the marsh cannot be fully evaluated until the end of the following summer. Changes in the management plan cannot be fully evaluated until another growth cycle has been completed, and so on.

Revegetation of bare areas can take as long as 3 years under restored hydrologic conditions (Faber 1983) if active measures are not implemented to improve the sediment quality in addition to resumption of flooding (recommendation 3). The response time of sediment salinity to increased flooding of the surface cannot be predicted, but it is reasonable to expect that a significant reduction of salinities can be achieved in the first year, depending on the frequency of flooding and the salinity of the flood water.

MONITORING PROGRAM

The objective of the monitoring program is to document the response of the critical soil and water quality parameters and of the ecosystem to changes in the hydrologic regime. The program necessarily has two phases: 1) document current conditions in the marsh, and 2) continuous monitoring of selected parameters coincident with managed changes in the hydrologic regime.

The monitoring program should keep track of moisture availability, salinity, and the size and density of the vegetation. The position of the water table, which can be measured directly in the field, can be used to measure the availability of moisture to the vegetation. Salinity of surface and pore waters can be measured quickly and to sufficient accuracy with a refractometer. Characteristics of the vegetation can be determined by standard survey techniques. Other variables of interest would be temperature and dissolved oxygen content in the sloughs and ponds, and water quality characteristics that pose a threat to health if concentrated in the surface water of the marsh. (Note: Heavy metals are generally removed from the water column as a result of contact with marsh sediments.)

The number of monitoring sites and the frequency of monitoring depend on the specific management objectives and the resources available. For instance, if it is decided to manage the hydrology to increase the density of vegetation, to revegetate areas of high salinity, and to maintain surface water quality, then the number of monitoring sites must be sufficient to characterize changes in these areas relative to controls in unmanaged areas. If a high frequency of flooding is imposed to quickly reduce sediment salinities, then frequent monitoring for sediment salinity should also be conducted. The details of the proposed changes to marsh hydrology are required before a detailed monitoring plan can be formulated.

## CONCLUSIONS

The distribution and productivity of the vegetation in salt marshes is controlled by the salinity and the degree of aeration of the sediment. The current stat of New Chicago marsh is a consequence of changes that have occurred in the salinity and aeration of the sediment as a result of cessation of tidal flooding. Four actions are recommended to improve the conditions in New Chicago marsh: 1) Resume flooding of the marsh surface, 2) Improve mixing in the ponds and sloughs, 3) Reclaim unvegetated areas, and 4) Implement improvements incrementally and in concert with a program of monitoring. The restoration of surface flooding in New Chicago marsh is the single most effective modification that can be made to improve the marsh in general and the habitat of the Harvest Mouse in particular. The degree to which the hydrology of the marsh must be managed for restoration is unprecedented and the full response of the ecosystem cannot be accurately predicted. Therefore, a gradual iterative process of hydrologic modification, monitoring, evaluation and planning subsequent modification is necessary to develop an efficient scheme for managing the hydrology for the restoration of New Chicago marsh.

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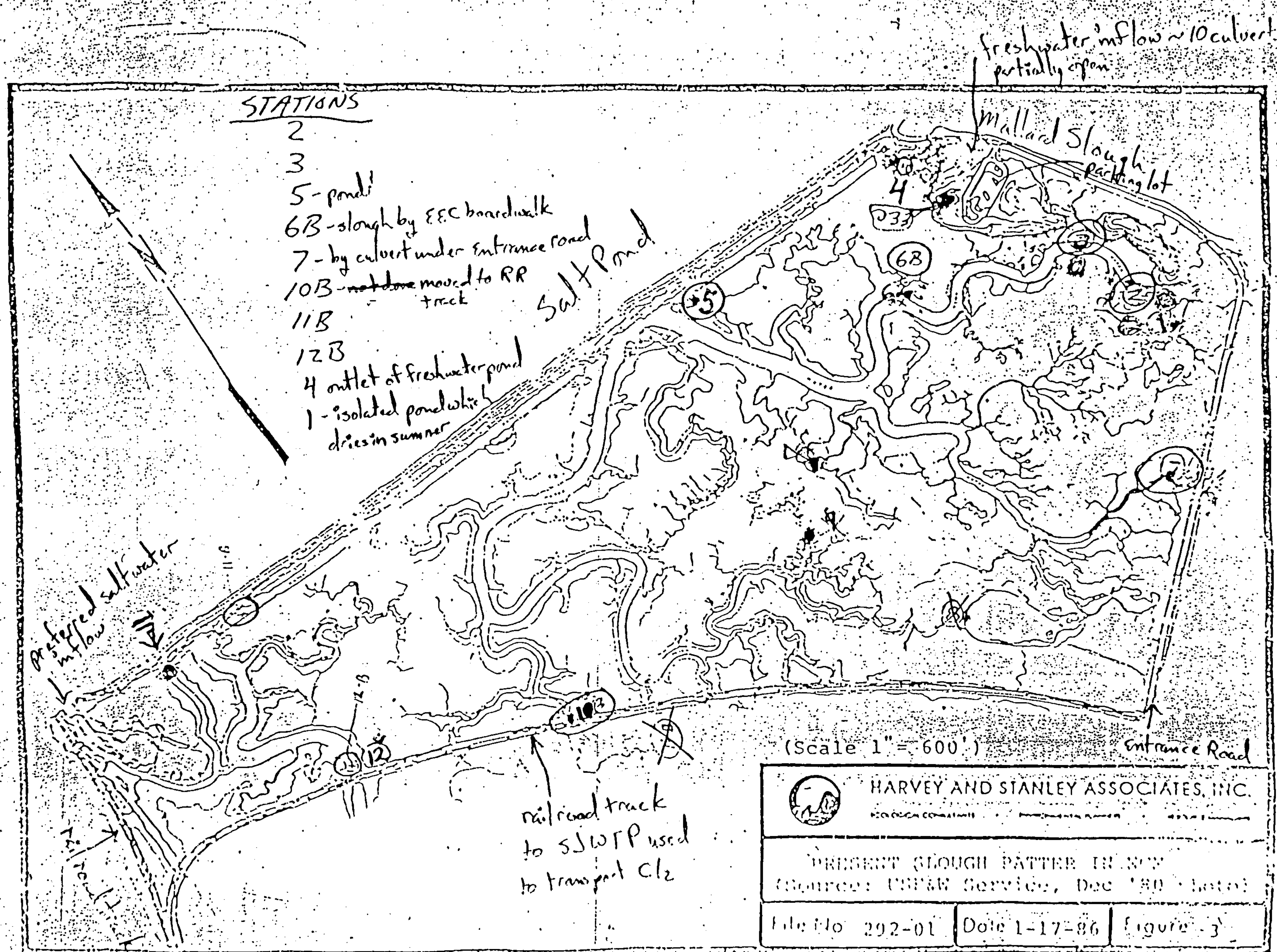
# APPENDIX B

## WATER QUALITY, SOIL SALINITY, AND GENERAL OBSERVATIONS BY STAFF AND VOLUNTEERS ENVIRONMENTAL EDUCATION CENTER, NEW CHICAGO MARSH, ALVISO, CALIFORNIA

1986-87 OBSERVERS:

RUSTY RYAN
LOUISE ACCURSO
KERI FITZ-HUGH
KIM DREYFUSS
BRUCE KENDAHL
DEBBY JOHNSTON


freshwater inflow ~ 10 culverts partially open
STATIONS
2
3
5 - pond!
6B - slough by EEC boardwalk
7 - by culvert under Entrance road
10B - ~~not done~~ moved to RR track
11B
12B
4 outlet of freshwater pond
1 - isolated pond which dries in summer
Salt Pond
Mallard Slough
parking lot
4
6B
5
12
preferred saltwater inflow
railroad track to SJWTP used to transport $Cl_2$
Entrance Road
(Scale 1" = 600')
HARVEY AND STANLEY ASSOCIATES, INC.
File No 292-01
Date 1-17-86
Figure 3

# NEW CHICAGO MARSH WATER SAMPLING DATA SHEET

DATE: 13 May 1986 AIR TEMP.(°C):

| SITE # | TIME | SALINITY | TEMP. | DIS. $O_2$ | pH | DEPTH |
|---|---|---|---|---|---|---|
| 1 | 1:45 | 17 | 26°C | | | |
| 2 | 1:30 | 12 | 22 | | | |
| 3 | | 13 | 23 | | | |
| 4 | | 2 | 28 | | | |
| 5 | | NOT TESTED | | | | |
| 6 | | NOT TESTED | | | | |
| 6B | | | | | | |
| 7 | | 14 | 23 | | | |
| 8 | 2:30 | 13 | 25 | | | |
| 9 | | NOT TESTED | | | | |
| 10 | | NOT TESTED | | | | |
| 10B | | | | | | |
| 11 | | NOT TESTED | | | | |
| 11B | | | | | | |
| 12 | 3:20 | 21 | 28 | | | |
| 12B | | | | | | |

DATE: 22 May, 1986 AIR TEMP.(°C):

| SITE # | TIME | SALINITY | TEMP. | DIS. $O_2$ | pH | DEPTH |
|---|---|---|---|---|---|---|
| 1 | 3.14 | 22 | 26°C | | | |
| 2 | 3:10 | 13 | 22 | | | |
| 3 | 3:00 | 13 | 20 | | | |
| 4 | 12.40 | 2 | 23 | | | |
| 5 | 11:00 | 20 | 17 | | | |
| 6 | 11:45 | 14 | 17 | | | 21cm |
| 6B | | | | | | |
| 7 | 3:15 | 13 | 16 | | | |
| 8 | 3:45 | 12 | 26 | | | |
| 9 | 4:05 | 14 | 28 | | | |
| 10 | 4:10 | 19 | 25 | | | |
| 10B | | | | | | |
| 11 | | 15 | 17 | | | |
| 11B | | | | | | |
| 12 | | 25 | 22 | | | |
| 12B | | | | | | |

# NEW CHICAGO MARSH WATER SAMPLING DATA SHEET

DATE: 29 May, 1986 AIR TEMP.(°C):

| SITE # | TIME | SALINITY | TEMP. | DIS. $O_2$ | pH | DEPTH |
|---|---|---|---|---|---|---|
| 1 | 11:00 | 73 | 27 | | | |
| 2 | | 35 | 24 | | | |
| 3 | 10:45 | 38 | 24 | | | |
| 4 | 10:15 | 5 | 24 | | | |
| 5 | 10:00 | 50 | 19 | | | |
| 6 | 10:30 | 35 | 19 | | | 16cm |
| 6B | | | | | | |
| 7 | 11:15 | 36 | 24 | | | |
| 8 | 11:30 | 38 | 26 | | | |
| 9 | 11:40 | 40 | 23 | | | |
| 10 | 11:45 | 62 | 32 | | | |
| 10B | | | | | | |
| 11 | 9:45 | 45 | 20 | | | |
| 11B | | | | | | |
| 12 | 9:20 | 82 | 17 | | | |
| 12B | (2) | *(32) | | | | |

DATE: 5 June, 1986 AIR TEMP.(°C):

| SITE # | TIME | SALINITY | TEMP. | DIS. $O_2$ | pH | DEPTH |
|---|---|---|---|---|---|---|
| 1 | 1:40 | 102 | 32°C | | | |
| 2 | | 42 | 28 | | | |
| 3 | 1:30 | 38 | 24 | | | |
| 4 | 1:05 | 12 | 32 | | | |
| 5 | 1:00 | 59 | 22 | | | |
| 6 | 1:20 | 35 | 23 | | | 11cm |
| 6B | | | | | | |
| 7 | 1:55 | 40 | 26 | | | |
| 8 | 2:10 | 43 | 30 | | | |
| 9 | 2:20 | 46 | 24 | | | |
| 10 | 2:40 | 102 | 35 | | | |
| 10B | | | | | | |
| (3) 11 | 12:20 | 52 | 28 | | | |
| 11B | ~~#?~~ | | | | | |
| 12 | 11:20 | 96 | 20 | | | |
| 12B | | | | | | |

* 32 was written for the salinity using the salinometer. for,

NEW CHICAGO MARSH WATER SAMPLING DATA SHEET

DATE: 12 June, 1986 AIR TEMP.(°C):

| SITE # | TIME | SALINITY | TEMP. | DIS. $O_2$ | pH | DEPTH |
|---|---|---|---|---|---|---|
| 1 | DRY → | | | | | |
| 2 | ~~47~~ | 42 | 28 | | 7.8 | |
| 3 | | 40 | 25 | | 8.6 | |
| 4 | DRY → | | | | | |
| 5 | | 53 | 24 | | 6.8 | |
| 6 | | 43 | 25 | | 8.6 | 6cm |
| 6B | | | | | | |
| 7 | | 42 | 25 | | 8.6 | |
| 8 | | 43 | 35 | | 9.3 | |
| 9 | | 50 | 26 | | 9.4 | |
| 10 | DRY → | | | | | |
| 10B | | ~~42~~ | | | | |
| 11 | | 92 | 30 | | 7.6 | |
| 11B | | | | | | |
| 12 | | 117 | 23 | (4) 6.6 | 5.8 | |
| 12B | | | | | | |

DATE: 18 June, 1986 AIR TEMP.(°C):

| SITE # | TIME | SALINITY | TEMP. | DIS. $O_2$ | pH | DEPTH |
|---|---|---|---|---|---|---|
| 1 | DRY → | | | | | |
| 2 | 11:00 | 42 | 26°C | | 6.6 | |
| 3 | 10:50 | 52 | 23 | | 6.8 | |
| 4 | DRY → | | | | | |
| 5 | 10:45 | 108 | 24 | | 6.6 | |
| 6 | 10:30 | 45 | 22 | | too dry | 2cm |
| 6B | ~~10~~ | | | | | |
| 7 | 11:06 | 42 | 23 | | 6.5 | |
| 8 | 11:30 | 46 | 27 | | 8.8 | |
| 9 | 11:40 | 54 | 24 | | | |
| 10 | DRY → | | | | | |
| 10B | | | | | | |
| 11 | DRY → | | | | | |
| 11B | | | | | | |
| 12 | 10:05 | 128 | 22 | | too cloudy | |
| 12B | | | | | | |

NEW CHICAGO MARSH WATER SAMPLING DATA SHEET

5 DATE: 26 June, 1986 AIR TEMP.(°C):

| SITE # | TIME | SALINITY | TEMP. | DIS. $O_2$ | pH | DEPTH |
|---|---|---|---|---|---|---|
| 1 | DRY | | | | | |
| 2 | | 50 | 29 | 8.5 | | too cloudy |
| 3 | | 55 | 26 | 8.4 | 8.6 | |
| 4 | DRY | | | | | |
| 5 | | 92 | 24 | 6.3 | 8.0 | |
| 6 | DRY | | | | | 6 7cm |
| 6B | | | | | | |
| 7 | | 50 | 23 | 8.9 | 7.6 | |
| 8 | DRY | | | | | |
| 9 | | 61 | 31 | 6.5 | 8.6 | |
| 10 | DRY | | | | | |
| 10B | | | | | | |
| 11 | DRY | | | | | |
| 11B | | | | | | |
| 12 | 15 | 158 | 25 | 9.4 | too cloudy | |
| 12B | | | | | | |

DATE: 3 July, 1986 AIR TEMP.(°C):

| SITE # | TIME | SALINITY | TEMP. | DIS. $O_2$ | pH | DEPTH |
|---|---|---|---|---|---|---|
| 1 | DRY | | | | | |
| 2 | ~~52~~ | 52 | 29°C | | 8.8 | |
| 3 | | 55 | 33 | | 9.1 | |
| 4 | DRY | | | | | |
| 5 | 12:00 | 105 | 31 | | 8.6 | |
| 6 | DRY | | | | | 3.5cm |
| 6B | | | | | | |
| 7 | | 50 | 25 | | 9.2 | |
| 8 | DRY | | | | | |
| 9 | | 98 | 33 | | 7.3 | |
| 10 | DRY | | | | | |
| 10B | | | | | | |
| 11 | DRY | | | | | |
| 11B | | | | | | |
| 12 | 11:45 | 170 | 34 | | too cloudy | |
| 12B | | | | | | |

[redacted] [redacted]

# NEW CHICAGO MARSH WATER SAMPLING DATA SHEET

DATE: 10 July, 1986 AIR TEMP. (°C):

| SITE # | TIME | SALINITY | TEMP. | DIS. $O_2$ | pH | DEPTH |
|---|---|---|---|---|---|---|
| 1 | DRY | | | | | |
| 2 | 11:20 | 66 | 30°C | | 7.4 | |
| 3 | 11:15 | 60 | 27 | | 9.7 | |
| 4 | DRY | | | | | |
| 5 | | 105 | 25 | | too cloudy | |
| 6 | DRY | | | | | ① 4cm. |
| 6B | | ~~50~~ | ~~25~~ | | | |
| 7 | | 50 | 25 | | 9.3 | |
| 8 | DRY | | | | | |
| 9 | | 110 | 33 | | too cloudy | |
| 10 | DRY | | | | | |
| 10B | | | | | | |
| 11 | DRY | | | | | |
| 11B | | | | | | |
| 12 | DRY | | | | | |
| 12B | | | | | | |

DATE: 18 July, 1986 AIR TEMP. (°C):

| SITE # | TIME | SALINITY | TEMP. | DIS. $O_2$ | pH | DEPTH |
|---|---|---|---|---|---|---|
| 1 | DRY | | | | | |
| 2 | 11:10 | 76 | 30°C | | 8.0 | |
| 3 | 10:45 | 68 | 26 | | 9.7 | |
| 4 | DRY | | | | | |
| 5 | 10:30 | 125 | 24 | | too cloudy | |
| 6 | DRY | | | | | 7cm |
| 6B | | | | | | |
| 7 | 11:00 | 50 | 20 | | 9.5 | |
| 8 | DRY | | | | | |
| 9 | 11:15 | 110 | 30 | | too cloudy | |
| 10 | DRY | | | | | |
| 10B | | | | | | |
| 11 | DRY | | | | | |
| 11B | | | | | | |
| 12 | DRY | | | | | |
| 12B | | | | | | |

[redacted] [redacted]

# NEW CHICAGO MARSH WATER SAMPLING DATA SHEET

DATE: 23 July, 1986 AIR TEMP. (°C):

| SITE # | TIME | SALINITY | TEMP. | DIS. $O_2$ | pH | DEPTH |
|---|---|---|---|---|---|---|
| 1 | DRY | | | | | |
| 2 | 10:55 | 80 | 25°C | | too cloudy | |
| 3 | 10:45 | 72 | 23 | | 8.5 | |
| 4 | DRY | | | | | |
| 5 | 10:30 | 135 | 24 | | too cloudy | |
| 6 | DRY | | | | | 2 cm |
| 6B | | | | | ~~too cloudy~~ | |
| 7 | 11:00 | 50 | 20 | | 9.5 | |
| 8 | DRY | | | | | |
| 9 | 11:15 DRY | | | | | |
| 10 | DRY | | | | | |
| 10B | | | | | | |
| 11 | DRY | | | | | |
| 11B | | | | | | |
| 12 | DRY | | | | | |
| 12B | | | | | | |

DATE: 30 July, 1986 AIR TEMP. (°C):

| SITE # | TIME | SALINITY | TEMP. | DIS. $O_2$ | pH | DEPTH |
|---|---|---|---|---|---|---|
| 1 | DRY | | | | | |
| 2 | 11:15 | 85 | 24 | No | pH. taken | |
| 3 | 11:30 | 74 | 25 | | | |
| 4 | DRY | | | | | |
| 5 | 10:00 | 148 | 22 | | | |
| 6 | | | | | | |
| S 6B | | 52 | 28 | | | 4 cm |
| 7 | 12:00 | 42 | 24 | | | |
| 8 | DRY | | | | | |
| 9 | DRY | | | | | |
| 10 | DRY | | | | | |
| 10B | | | | | | |
| P 11 | | | | | | |
| 11B | 10:15 | 90 | 25 | | | |
| 12 | DRY | | | | | |
| 12B | | | | | | |

NEW CHICAGO MARSH WATER SAMPLING DATA SHEET

DATE: 6 Aug 1986 AIR TEMP.(°C):

| SITE # | TIME | SALINITY | TEMP. | DIS. $O_2$ | pH | DEPTH |
|---|---|---|---|---|---|---|
| 1 | DRY | | | | | |
| 2 | 1:10 | 68 | 36°C | | | |
| 3 | 1:00 | 52 | 30 | | | |
| 4 | DRY | | | | | |
| 5 | 11:50 | 148 | 28 | | | |
| 6 | | | | | | |
| 6B | 11:30 | 28 | 26 | | | 0cm |
| 7 | 1:15 | 45 | 24 | | | |
| 8 | DRY | | | | | |
| 9 | DRY | | | | | |
| 10 | | | | | | |
| 10B | 12:20 | 65 | 19 | | 9.7 | |
| 11 | | | | | | |
| 11B | 12:30 | 99 | 30 | | | |
| 12 | | | | | | |
| 12B | | 97 | 22 | | | |

DATE: 13 Aug. 1986 AIR TEMP.(°C):

| SITE # | TIME | SALINITY | TEMP. | DIS. $O_2$ | pH | DEPTH |
|---|---|---|---|---|---|---|
| 1 | DRY | | | | | |
| 2 | 1:20 | 49 | 34°C | | 7.7 | |
| 3 | 1:05 | 50 | 27 | | 8.7 | |
| 4 | DRY | | | | | |
| 5 | 12:00 | 158 | 26 | | 9.0 | |
| 6 | | | | | | |
| 6B | 11:45 | 28 | 30 | | 8.3 | 0cm. |
| 7 | | 45 | 28 | | 9.2 | |
| 8 | DRY | | | | | |
| 9 | DRY | | | | | |
| 10 | | | | | | |
| 10B | 12:40 | 65 | 18 | | too cloudy | |
| 11 | | | | | | |
| 11B | 12:15 | 122 | 30 | | too cloudy | |
| 12 | | | | | | |
| 12B | 12:30 | 100 | 24 | | too cloudy | |

[redacted]

# NEW CHICAGO MARSH WATER SAMPLING DATA SHEET

DATE: 21 Aug. 1986 AIR TEMP.(°C):

| SITE # | TIME | SALINITY | TEMP. | DIS. $O_2$ | pH | DEPTH |
|---|---|---|---|---|---|---|
| 1 | DRY → | | | | | |
| 2 | 12.45 | 10 51 | 28°C | 1.2 | too cloudy | |
| 3 | 12:30 | 43 | 25 | 4.2 | 8.6 | |
| 4 | DRY → | | | | | |
| 5 | 11:20 | 160+ | 22 | 1.4 | 8.3 | |
| 6 | | | | | | |
| 6B | 11:00 | 31 | 22 | 3.0 | 9.1 | 0cm |
| 7 | 1:15 | 45 | 20 | 5.8 | 10 | |
| 8 | DRY → | | | | | |
| 9 | DRY → | | | | | |
| 10 | | | | | | |
| 10B | 12:05 | 70 | 26 | 1.0 | 8.2 | |
| 11 | | | | | | |
| 11B | 11.35 | 160+ | 26 | .6 | too cloudy | |
| 12 | | | | | | |
| 12B | 12:00 | 108 | 26 | 1.2 | 9.3 | |

DATE: 27 Aug. 1986 AIR TEMP.(°C):

| SITE # | TIME | SALINITY | TEMP. | DIS. $O_2$ | pH | DEPTH |
|---|---|---|---|---|---|---|
| 1 | DRY → | | | | | |
| 2 | 2:25 | 54 | 30°C | No $DO_2$ taken | 9.4 Raindrop | |
| 3 | 2:35 | 38 | 27 | | 8.7 | |
| 4 | DRY → | | | | 8.7 | |
| 5 | 2:45 | (1.3640) 160+ | 30 | | 8.1 | |
| 6 | | | | | | |
| 6B | 3.45 | 34 | 30 | | 9.6 | 0cm |
| 7 | 2:15 | 44 | 26 | | 10 | |
| 8 | DRY → | | | | | |
| 9 | DRY → | | | | | |
| 10 | | | | | | |
| 10B | 3:25 | 67 | 20 | | 8.9 | |
| 11 | | | | | | |
| 11B | 2:55 | 1.3720 160+ | 34 | | 7.5 | |
| 12 | | | | | | |
| 12B | 315 | 108 | 24 | | 7.9 | |

NEW CHICAGO MARSH WATER SAMPLING DATA SHEET.

DATE: 27 Aug. 1986 AIR TEMP.(°C):

| SITE # | TIME | SALINITY | TEMP. | DIS. $O_2$ | pH | DEPTH |
|---|---|---|---|---|---|---|
| 1 | DRY | | | | | |
| 2 | 2:25 | 54 | 30°C | | 9.3 | |
| 3 | 2:35 | 38 | 27°C | | 8.8 | |
| 4 | DRY | | | | | |
| 5 | 2:45 | (11) (1.3440) 160+ | 30 | | 8.2 | |
| 6 | | | | | | |
| 6B | 3.45 | 34 | 30 | | 9.4 | 0cm |
| 7 | 2:15 | 44 | 26 | | 10 | |
| 8 | DRY | | | | | |
| 9 | DRY | | | | | |
| 10 | | | | | | |
| 10B | 3:25 | 67 | 20 | | 8.9 | |
| 11 | | | | | | |
| 11B | 2:55 | (1.3120) 160+ | 34 | | 7.4 | |
| 12 | | | | | | |
| 12B | 3:15 | 108 | 29 | | 7.8 | |

DATE: 4 Sept. 1986 AIR TEMP.(°C):

| SITE # | TIME | SALINITY | TEMP. | DIS. $O_2$ | pH | DEPTH |
|---|---|---|---|---|---|---|
| 1 | | | | | | |
| 2 | | | | | 8.9 | |
| 3 | | | | | 8.4 | |
| 4 | | | | | | |
| 5 | | | | | 8.2 | |
| 6 | | | | | | |
| 6B | | | | | 8.7 | |
| 7 | | | | | 9.6 | |
| 8 | | | | | | |
| 9 | | | | | | |
| 10 | | | | | | |
| 10B | | | | | 8.9 | |
| 11 | | | | | | |
| 11B | | | | | 7.4 | |
| 12 | | | | | | |
| 12B | | | | | too cloudy | to zero |

[redacted] [redacted]

# NEW CHICAGO MARSH WATER SAMPLING DATA SHEET

DATE: 4 SEPT. 1986 AIR TEMP.(°C):

| SITE # | TIME | SALINITY | TEMP. | DIS. $O_2$ | pH | DEPTH |
|---|---|---|---|---|---|---|
| 1 | | | | | | |
| 2 | 10:50 | 65 | 21 | 3.5 | 8.9 | |
| 3 | 11:05 | 41 | 23 | 1.4 | 8.4 | |
| 4 | | | | | | |
| 5 | 11:20 | (1.3649) 160+ | 30°C | 7.0 | 8.2 | |
| 6 | | | | | | |
| 6B | 12:50 | 30 | 25 | 3.0 | 8.7 | |
| 7 | 10:40 | 38 | 19 | 2.0 | 9.6 | |
| 8 | | | | | | |
| 9 | | | | | | |
| 10 | | | | | | |
| 10B | 12:10 | 69 | 24 | .6 | 8.9 | |
| 11 | | | | | | |
| 11B | 11:35 | (off scale) 160+ | 27 | 4.2 | 7.4 | |
| 12 | | | | | | |
| 12B | 11:55 | 111 | 24 | 1.7 | too cloudy to zero | |

DATE: 10 SEPT. 1986 AIR TEMP.(°C):

| SITE # | TIME | SALINITY | TEMP. | DIS. $O_2$ | pH | DEPTH |
|---|---|---|---|---|---|---|
| 1 | | | | | | |
| 2 | 10:40 AM | 65 | 22.5°C | 13ppt | 9.3 | |
| 3 | 10:50 | 35 | 20 | 2 | 8.6 | |
| 4 | | | | | | |
| 5 | 11:05 | (13649) 160+ | 22 | 14.2 | too cloudy | |
| 6 | | | | | | |
| 6B | 12:15 | 32 | 22 | 2.6 | 9.0 | 0 cm. |
| 7 | 10:30 | 36 | 17.5 | 4.3 | 9.8 | |
| 8 | | | | | | |
| 9 | | | | | | |
| 10 | | | | | | |
| 10B | 11:40 | 113 | 20 | .7 | too cloudy | |
| 11 | | | | | | |
| 11B | 11:15 | (off scale) 160+ | 29 | 4.8 | 7.8 | |
| 12 | | | | | | |
| 12B | 11:50 | 61 | 21 | 0 | 9.5 | |

# NEW CHICAGO MARSH WATER SAMPLING DATA SHEET

12

DATE: 18 SEPT. 1986 AIR TEMP.(°C): 23°C
Clear, very windy

| SITE # | TIME | SALINITY | TEMP. | DIS. $O_2$ | pH | DEPTH |
|---|---|---|---|---|---|---|
| 1 | | | | NO METER | | |
| 2 | 3:15 | 36 | 23°C | | 9.0 | |
| 3 | 3:20 | 24 | 24 | | 9.2 | |
| 4 | | | | | | |
| 5 | 3:30 | 102 | 24 | | too cloudy | 13 |
| 6 | | | | | | |
| 6B | 4:35 | 4 | 22 | | 9.0 | +4cm |
| 7 | 3:10 | 8 | 20 | | 9.4 | |
| 8 | | | | | | |
| 9 | | | | | | |
| 10 | | | | | | |
| 10B | 4:00 | 30 | 22 | | 9.3 | |
| 11 | | | | | | |
| 11B | 3:35 | 22 | 28 | | 8.9 | |
| 12 | | | | | | |
| 12B | 3:55 | 45 | 18 | | 9.7 | |

DATE: 25 SEPT. 1986 AIR TEMP.(°C):
RAINING

| SITE # | TIME | SALINITY | TEMP. | DIS. $O_2$ | pH | DEPTH |
|---|---|---|---|---|---|---|
| 1 | | | | | | |
| 2 | 12:30 | 18 | 23°C | 7.2 | 9.3 | |
| 3 | 12:40 | 12 | 18 | 9.0 | 9.5 | |
| 4 | | | | | | |
| 5 | 1:00 | 85 | 24 | 1.4 | too cloudy | |
| 6 | | | | | | |
| 6B | 1:50 | 6 | 20 | 3.6 | 9.2 | +.5cm |
| 7 | 12:20 | 9 | 18 | 5.8 | 9.4 | |
| 8 | | | | | | |
| 9 | | | | | | |
| 10 | | | | | | |
| 10B | 11:50 | 27 | 17 | 7.0 | 9.1 | |
| 11 | | | | | | |
| 11B | 1:25 | 9 | 18 | 11.4 | 9.3 | |
| 12 | | | | | | |
| 12B | 12:05 | 18 | 18 | 7.4 | 9.6 | |

# NEW CHICAGO MARSH WATER SAMPLING DATA SHEET

DATE: 2 Oct, 1986    AIR TEMP. (°C):

| SITE # | TIME | SALINITY | TEMP. | DIS. $O_2$ | pH | DEPTH |
|---|---|---|---|---|---|---|
| 1 | | | | | | |
| 2 | 10:05 | 21 | 16°C | * 9.2 | 9.2 | |
| 3 | 10:10 | 11 | 21°C | 9.8 | 9.5 | |
| 4 | | | | | | |
| 5 | 10:30 | 96 | 18°C | .2 | 8.0 | |
| 6 | | | | | | |
| 6B | 11:20 | 7 | 16°C | 11.0 | 9.3 | + (20.5cm) |
| 7 | 9.45 | 9 | 13°C | 3.7 | 9.5 | |
| 8 | | | | | | |
| 9 | | | | | | |
| 10 | | | | | | |
| 10B | 9:15 | 6 | 14°C | 4.2 | 9.5 | |
| 11 | | | | | | |
| 11B | 10:50 | 15 | 19°C | 5.4 | 9.3 | |
| 12 | | | | | | |
| 12B | 9.25 | 12 | 13°C | 2.5 | 9.5 | |

DATE: 9 Oct. 1986    AIR TEMP. (°C): dense fog

| SITE # | TIME | SALINITY | TEMP. | DIS. $O_2$ | pH | DEPTH |
|---|---|---|---|---|---|---|
| 1 | | | | | IN FIELD W/METER | INLAB W/METER / W/HACH |
| 2 | 10:30 | 10 | 16°C | 1.7 * | 9.14 | 9.08/9.0 |
| 3 | 10:40 | 7 | 17°C | 2.8 | 9.19 | 9.14/9.2 |
| 4 | | | | | | |
| 5 | 11:10 | 78 | 19°C | 8.0 | 7.78 | 7.65/7.5 |
| 6 | | | | | | |
| 6B | 12:10 | 6 | 20°C | 7.0 | 9.45 | 8.74/8.7 +5 (25cm) |
| 7 | 10:20 | 6 | 16°C | 5.1 | 9.19 | 9.15/9.1 |
| 8 | | | | | | |
| 9 | | | | | | |
| 10 | | | | | | |
| 10B | 9:50 | 6 | 16°C | 1.3 | 9.26 | 9.25/9.2 |
| 11 | | | | | | |
| 11B | 11:30 | 10 | 20°C | 7.6 | 9.04 | 9.01/9.1 |
| 12 | | | | | | |
| 12B | 10:00 | 9 | 17°C | 1.4 | 9.50 | 9.41/9.35 |

[redacted] [redacted] [redacted]

# NEW CHICAGO MARSH WATER SAMPLING DATA SHEET

DATE: 16 Oct. 1986 AIR TEMP.(°C):

| SITE # | TIME | SALINITY | TEMP. | DIS. $O_2$ | pH | DEPTH |
|---|---|---|---|---|---|---|
| 1 | | | | | | |
| 2 | 3:05 | 10 | 22°C | .7 | 8.6 | |
| 3 | 3:15 | 9 | 21°C | 8.8 | 8.5 | |
| 4 | | | | | | |
| 5 | 3:30 | 83 | 22°C | 9.4 | 7.7 | |
| 6 | | | | | | |
| 6B | 4:05 | 7 | 21°C | 6.4 | 7.6 | (27cm) |
| 7 | 2:50 | 8 | 21°C | .5 | 8.5 | |
| 8 | | | | | | |
| 9 | | | | | | |
| 10 | | | | | | |
| 10B | 2:10 | 8 | 20°C | 7.2 | 8.7 | |
| 11 | | | | | | |
| 11B | 3:45 | 10 | 21°C | 11.2 | 8.7 | |
| 12 | | | | | | |
| 12B | 2:25 | 8 | 19°C | 13.8 | 10.0 ~~8.0~~ | |

DATE: 23 Oct. 1986 AIR TEMP.(°C): 15°C
foggy

| SITE # | TIME | SALINITY | TEMP. | DIS. $O_2$ | pH | DEPTH |
|---|---|---|---|---|---|---|
| 1 | | | | | | |
| 2 | 9:50 | 6 | 15.0° | .55 | | 8.9cm ~~3.5~~ |
| 3 | 10:00 | 6 | 16.0 | 2.55 | | |
| 4 | | | | | | |
| 5 | 10:35 | 80 | 16.2 | 11.5 | | 40.6cm |
| 6 | | | | | | |
| 6B | 12:00 | 6 | 17.5 | 4.0 | | 30cm |
| 7 | 9:35 | 5 | 15.0 | .30 | | ~~30.5cm~~ |
| 8 | | | | | | |
| 9 | | | | | | |
| 10 | | | | | | |
| 10B | 9:05 | 8 | 15.5 | 1.20 | | 30.5cm |
| 11 | | | | | | |
| 11B | 10:25 | 7 | 15.5 | 16.0 | | 21.6cm |
| 12 | | | | | | |
| 12B | 9:15 | 7 | 15.7 | .35 | | |

NEW CHICAGO MARSH WATER SAMPLING DATA SHEET

DATE: 11/20/06 AIR TEMP.(°C): 10 Am / 12:30 PM 18°C

* SFBBO pH meter

| SITE # | TIME | SALINITY | TEMP. °C | DIS. $O_2$ | * pH | DEPTH |
|---|---|---|---|---|---|---|
| 1 | DRY | — | — | — | — | — |
| 2 | 12:50 P. | 7 | 15 | 6.2 | 8.0 | |
| 3 | 1:05 P. | 6 | 15 | 5.6 | 7.8 | |
| 4 | DRY | — | — | — | — | — |
| 5 | 10:45 A. | 55 | 16 | 12.5 | 9.1 | |
| 6 | | | | | | |
| 6B | 10:05 A | 7 | 13 | 4.3 | 10.2 | |
| 7 | 12:30 P | 6 | 14 | 4.2 | 8.2 | |
| 8 | | | | | | |
| 9 | | | | | | |
| 10 | | | | | | |
| 10B | 12 PM | 5 | 13 | 5.8 | 8.2 | |
| 11 | | | | | | |
| 11B | 11:15 A. | 8 | 14 | 17.4 | 10.1 | |
| 12 | DRY | — | — | — | — | — |
| 12B | 11:45 A. | 16 | 15 | 13.7 | 10.4 | ALGAE |

DATE: 11/20/06 AIR TEMP.(°C):

* New pH indic. solution

| SITE # | TIME | SALINITY | TEMP. | DIS. $O_2$ | * pH | DEPTH |
|---|---|---|---|---|---|---|
| 1 | | | | | 15 Dps | 20 Dps |
| 2 | | | | | 8.9 | |
| 3 | | | | | 8.6 | |
| 4 | | | | | | |
| 5 | | | | | 8.0 | |
| 6 | | | | | | |
| 6B | | | | | 8.9 | |
| 7 | | | | | 8.7 | 9.0 |
| 8 | | SALT POND | | | AT N.C.M. | |
| [illegible] | 1:30 P. | 66 | 17 | 10.1 | 8.1 - meter | |
| 10 | | | | | 9.2 - solut. | |
| 10B | | | | | 8.6 | |
| 11 | | | | | | |
| 11B | | | | | 9.2 | |
| 12 | | | | | | |
| 12B | | | | | 9.4 | 9.6 |

R. L. Ryan

TIME ~ 1000 ÷ 1300

NEW CHICAGO MARSH WATER SAMPLING DATA SHEET

DATE: 11-26-86 AIR TEMP.(°C): 10:15 Am 13°C

Military

| SITE # | TIME | SALINITY | TEMP. | DIS. $O_2$ | pH | DEPTH |
|---|---|---|---|---|---|---|
| 1 | | | | | meter | * solut. |
| 2 | 1250 | 7 | 10 | 7 | 7.4 | 8.8 |
| 3 | 1305 | 7 | 11 | 6.3 | 7.3 | 8.7 |
| 4 | | | | | | |
| 5 | 1050 | 54 | 12 | 11 | 7.0 | 8.1 |
| 6 | | | | | | |
| 6B | 1015 | 5 | 8 | 5.3 | 7.9 | 8.9 |
| 7 | 1230 | 7 | 9 | 3.9 | 7.4 | 8.9 |
| 8 | | | | | | |
| 9 | | | | | | |
| 10 | | | | | | |
| 10B | 1205 | 5 | 9 | 6 | 7.6 | 8.8 |
| 11 | | | | | | |
| * 11B | 1120 | 12 | 12 | 20+ | 8.9 | 9.6 |
| 12 | | | | (3X) ↑ | | |
| 12B | 1150 | 12 | 17.8 | 17.8 | 8.7 | 9.4 |

DATE: AIR TEMP.(°C):

Alviso - SALT POND

| SITE # | TIME | SALINITY | TEMP. | DIS. $O_2$ | pH | DEPTH |
|---|---|---|---|---|---|---|
| 1 | 1320 | 67 | 12 | 10.4 | 7.6 | 9.2 |
| 2 | | | | | | |
| 3 | | | | | | |
| 4 | | | | | | |
| 5 | | | | | | |
| 6 | | | | | | |
| 6B | | | | | | |
| 7 | | | | | | |
| 8 | | | | | | |
| 9 | | | | | | |
| 10 | | | | | | |
| 10B | | | | | | |
| 11 | | | | | | |
| 11B | | | | | | |
| 12 | | | | | | |
| 12B | | | | | | |

R. L. Ryan

** DO METER BROKE

NEW CHICAGO MARSH WATER SAMPLING DATA SHEET

DATE: 12-4-86 AIR TEMP.(°C): At 1045 WAS 12°C

WEATHER - OVERCAST AND cool

| SITE # | TIME | SALINITY | TEMP. | DIS. $O_2$ | pH | ~~DEPTH~~ |
|---|---|---|---|---|---|---|
| 1 | | | | | (meter) | (solutn.) |
| 2 | 1250 | 6 | 8 | — | 7.2 | 8.7 |
| 3 | 1300 | 6 | 8 | — | 7.2 | 8.6 |
| 4 | | | | | | |
| 5 | 1115 | 51 | 11 | — | 6.3 | 7.9 |
| 6 | | | | | | |
| 6B | 1045 | 6 | 9 | 3.6 | 7.5 | 8.5 |
| 7 | 1240 | 6 | 7 | — | 7.2 | 8.7 |
| 8 | | | | | | |
| 9 | | | | | | |
| 10 | | | | | | |
| 10B | 1215 | 5 | 8 | — | 7.3 | 8.6 |
| 11 | | | | | | |
| 11B | 1150 | 8 | 9 | — | 8.1 | 9.1 |
| 12 | | | | | | |
| 12B | 1205 | 11 | 10 | — | 8.5 | 9.3 |

DATE: AIR TEMP.(°C):

| SITE # | TIME | SALINITY | TEMP. | DIS. $O_2$ | pH | ~~DEPTH~~ |
|---|---|---|---|---|---|---|
| 1 | | | | | (meter) | (solutn.) |
| 2 | | | | | | |
| 3 | | | | | | |
| 4 | | | | | | |
| 5 | | | | | | |
| 6 | | | | | | |
| 6B | | | | | | 5.06 DEPTH |
| 7 | | | | | | |
| 8 | | | | | | |
| 9 | | | | | | |
| 10 | SALT POND | | | | | |
| 10B | | | | | | |
| 11 | 1345 | 66 | 10 | — | 7.4 | 9.0 |
| 11B | | | | | | |
| 12 | | | | | | |
| 12B | | | | | | |

*↖ completed AT 1614 hours

R. L. Ryan

# NEW CHICAGO MARSH WATER SAMPLING DATA SHEET

* USED SF1950
Dis. $O_2$ meter * no

DATE: 12-11-86 AIR TEMP.(°C): 12°C AT 1005 hrs

cool, cloudy

| SITE # | TIME | SALINITY | TEMP. | DIS. $O_2$ | pH paper | pH ~~DEPTH~~ meter |
|---|---|---|---|---|---|---|
| 1 | | | | | | |
| 2 | 1235 | 2 | 6 | 8.8 | 5.5 | 6.6 |
| 3 | 1250 | 2 | 7 | 8.4 | 5.8 | 6.6 |
| 4 | | | | | | |
| 5 | 1050 | 33 | 10 | 16.6 | 5.5 | 5.8 |
| 6 | | | | | | |
| 6B | 1005 | 3 | 5 | 6.8 | 5.5 | 7.4 |
| 7 | 1225 | 2 | 6 | 6.4 | 5.5 | 6.5 |
| 8 | | | | | | |
| 9 | | | | | | |
| 10 | | | | | | |
| 10B | 1155 | *0 | 6 | 8.4 | 5.5 | 6.5 |
| 11 | | | | | | |
| 11B | 1115 | 4 | 8 | *20 | 5.8 | 6.5 |
| 12 | | | | | | |
| 12B | 1140 | 6 | 6 | 18.8 | 5.8 | 7.1 |

DATE: AIR TEMP.(°C):
SAlinity corr. factor

| SITE # | TIME | SALINITY | TEMP. | DIS. $O_2$ | pH | DEPTH |
|---|---|---|---|---|---|---|
| 1 | | | | | | |
| 2 | | | | | | |
| 3 | | | | | | |
| 4 | | | | | | |
| 5 | | | | | | |
| 6 | | | | | | DEPTH |
| 6B | | | | | | 4.99 |
| 7 | | | | | | |
| 8 | | | | | | |
| 9 | | | | | | |
| [illegible] | SALT | POND | | | paper | meter |
| [illegible] | 1300 | 60 | 9 | 16.6 | 6.5 | 7.2 |
| 11 | | | | | | |
| 11B | | | | | | |
| 12 | | | | | | |
| 12B | | | | | | |

[redacted]

R. L. Ryan

WEATHER - C[illegible] AND SUNNY

NEW CHICAGO MARSH WATER SAMPLING DATA SHEET

** USED SF000 Dis $O_2$ meter, I DID * use the SALINITY corr. factor

DATE: FRI. 12-19-86 AIR TEMP. (°C): 10°C At 0945 hrs.

DATE: AIR TEMP. (°C):

Alviso SALT pond

| SITE # | TIME | SALINITY | TEMP. | DIS. $O_2$ | pH paper | [redacted] meter | SITE # | TIME | SALINITY | TEMP. | DIS. $O_2$ | pH paper | [redacted] meter |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | 1 | 1230 | 61 | 8 | 6.1 | 6.5 | 7.3 |
| 2 | | 5 | 10 | 1.8 | 5.5 | 6.7 | 2 | | | | | | |
| 3 | | 4 | 9 | 5.0 | 5.5 | 6.8 | 3 | | | | | | |
| 4 | | | | | | | 4 | | | | | | |
| 5 | | 27 | 9 | *20 | 5.5 | 6.4 | 5 | | | | | | |
| 6 | | | | | | | 6 | | | | | | DEPTH |
| 6B | 0945 | 5 | 8 | 5 | 5.5 | 7.1 | 6B | → | | | | | 4.90' |
| 7 | | 6 | 11 | *0.4 | 5.5 | 6.8 | 7 | | | | | | |
| 8 | | | | | | | 8 | | | | | | |
| 9 | | | | | | | 9 | | | | | | |
| 10 | | | | | | | 10 | | | | | | |
| 10B | | 3 | 9 | 8.9 | 5.5 | 6.9 | 10B | | | | | | |
| 11 | | | | | | | 11 | | | | | | DEPTH |
| 11B | | 4 | 8 | 5.8 | 5.5 | 6.6 | 11B | → | | | | | 4.90' |
| 12 | | | | | | | 12 | | | | | | |
| 12B | | 10 | 10 | 4.8 | 5.5 | 7.2 | 12B | | | | | | |

* TIME ~ 0945 hours - 1230 hours →

NEW CHICAGO MARSH WA SAMPLING DATA SHEET

DATE: 2/6/81 AIR TEMP.(°C): 20

| SITE # | TIME | SALINITY | TEMP. | DIS. $O_2$ | pH | DEPTH |
|---|---|---|---|---|---|---|
| 1 | | | | | | |
| 2 | 15:24 | 8.0 | 17.0°C | 20+ | 7.4 | |
| 3 | 15:20 | 7.5 | 16.1°C | 20+ | 7.2 | |
| 4 | 15:01 | 2.0 | 20°C | 20+ | 6.2 | |
| 5 | 14:0[illegible] | 18.0 | 21°C | 20+ | 7.2 | |
| 6 | | | | | | |
| 6B | 15:05 | 13.0 | 15°C | 8.8 | 6.3 | |
| 7 | 15:31 | 16.0 | 16°C | 7.0 | 6.3 | |
| 8 | | | | | | |
| 9 | | | | | | |
| 10 | | | | | | |
| 10B | 15:10 | 13.5 | 15.5 | 7.2 | 7.8 | |
| 11 | 14:25 | 12.0 | 18.5°C | 6.2 | [illegible] | |
| 11B | | | | | | |
| 12 | 14:55 | 30.0 | 21° | 6.9 | 6.7 | |
| 12B | 14:50 | 20.0 | 17°C | 6.0 | 7.7 | |

DATE: AIR TEMP.(°C):

| SITE # | TIME | SALINITY | TEMP. | DIS. $O_2$ | pH | DEPTH |
|---|---|---|---|---|---|---|
| 1 | | | | | | |
| 2 | | | | | | |
| 3 | | | | | | |
| 4 | | | | | | |
| 5 | | | | | | |
| 6 | | | | | | |
| 6B | | | | | | |
| 7 | | | | | | |
| 8 | | | | | | |
| 9 | | | | | | |
| 10 | | | | | | |
| 10B | | | | | | |
| 11 | | | | | | |
| 11B | | | | | | |
| 12 | | | | | | |
| 12B | | | | | | |

KERI FITZ-HUGH

NEW CHICAGO MARSH WA[illegible] SAMPLING DATA SHEET

DATE: 2/20/87 AIR TEMP.(°C): 15.2°C

| SITE # | TIME | SALINITY | TEMP. | DIS. $O_2$ | pH | DEPTH |
|---|---|---|---|---|---|---|
| 1 | | | | | | |
| 2 | 16:[illegible] | 20 | 7.8°C | 11.0 | [illegible] | |
| 3 | [illegible] | 15 | 7.6°C | 10.2 | [illegible] | |
| 4 | 14:42 | 20 | 10°C | 17.6 | 7.7 | |
| 5 | | | | | | |
| 6 | | | | | | |
| 6B | 14:35 | 15 | 8°C | 12.0 | 8.0 | |
| 7 | 15:55 | 20 | 7.5° | 10.0 | 2.2 | |
| 8 | | | | | | |
| 9 | | | | | | |
| 10 | | | | | | |
| 10B | 15:42 | 15 | 8° | 11.8 | 7.7 | |
| 11 | | | | | | |
| 11B | 1[illegible] | 22 | 8°C | 14.8 | 6.2 | |
| 12 | 15:22 | 24 | [illegible] | 10.2 | 7.3 | |
| 12B | [illegible] | [illegible] | | | | |

DATE: AIR TEMP.(°C):

| SITE # | TIME | SALINITY | TEMP. | DIS. $O_2$ | pH | DEPTH |
|---|---|---|---|---|---|---|
| 1 | | | | | | |
| 2 | | | | | | |
| 3 | | | | | | |
| 4 | | | | | | |
| 5 | | | | | | |
| 6 | | | | | | |
| 6B | | | | | | |
| 7 | | | | | | |
| 8 | | | | | | |
| 9 | | | | | | |
| 10 | | | | | | |
| 10B | | | | | | |
| 11 | | | | | | |
| 11B | | | | | | |
| 12 | | | | | | |
| 12B | | | | | | |

NEW CHICAGO MARSH W[illegible] SAMPLING DATA SHEET

DATE: 2/26/[illegible] AIR TEMP.(°C): 17

| SITE # | TIME | SALINITY | TEMP. | DIS. $O_2$ | pH | DEPTH |
|---|---|---|---|---|---|---|
| 1 | | | | | | |
| 2 | [illegible] | | | [illegible] | [illegible] | |
| 3 | [illegible] | [illegible] | 7.7 | [illegible] | [illegible] | |
| 4 | [illegible] | | [illegible] | | | |
| 5 | | | | | | |
| 6 | | | | | | |
| 6B | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | |
| 7 | [illegible] | 15.5 | [illegible] | [illegible] | [illegible] | |
| 8 | | | | | | |
| 9 | | | | | | |
| 10 | | | | | | |
| 10B | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | |
| 11 | | | | | | |
| 11B | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | |
| 12 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | |
| 12B | [illegible] | [illegible] | [illegible] | [illegible] | 7.7 | |

DATE: AIR TEMP.(°C):

| SITE # | TIME | SALINITY | TEMP. | DIS. $O_2$ | pH | DEPTH |
|---|---|---|---|---|---|---|
| 1 | | | | | | |
| 2 | | | | | | |
| 3 | | | | | | |
| 4 | | | | | | |
| 5 | | | | | | |
| 6 | | | | | | |
| 6B | | | | | | |
| 7 | | | | | | |
| 8 | | | | | | |
| 9 | | | | | | |
| 10 | | | | | | |
| 10B | | | | | | |
| 11 | | | | | | |
| 11B | | | | | | |
| 12 | | | | | | |
| 12B | | | | | | |

NEW CHICAGO MARSH W/ SAMPLING DATA SHEET

DATE: [illegible] AIR TEMP.(°C): [illegible]

| SITE # | TIME | SALINITY | TEMP. | DIS. $O_2$ | pH | DEPTH |
|---|---|---|---|---|---|---|
| 1 | | | | | | |
| 2 | | [illegible] | [illegible] | [illegible] | | |
| 3 | | | | | | |
| 4 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | |
| 5 | | [illegible] | | | | |
| 6 | | | | | | |
| 6B | [illegible] | [illegible] | [illegible] | [illegible] | | |
| 7 | 14:55 | | [illegible] | [illegible] | | |
| 8 | | | | | | |
| 9 | | | | | | |
| 10 | | | | | | |
| 10B | 15:55 | [illegible] | | | | |
| 11 | | | | | | |
| 11B | [illegible] | | | [illegible] | [illegible] | |
| 12 | [illegible] | | | | [illegible] | |
| 12B | | | | | | |

DATE: AIR TEMP.(°C): 60

| SITE # | TIME | SALINITY | TEMP. | DIS. $O_2$ | pH | DEPTH |
|---|---|---|---|---|---|---|
| 1 | | | | | | |
| 2 | | | | | | |
| 3 | | | | | | |
| 4 | | | | | | |
| 5 | | | | | | |
| 6 | | | | | | |
| 6B | | | | | | |
| 7 | | | | | | |
| 8 | | | | | | |
| 9 | | | | | | |
| 10 | | | | | | |
| 10B | | | | | | |
| 11 | | | | | | |
| 11B | | | | | | |
| 12 | | | | | | |
| 12B | | | | | | |

NEW CHICAGO MARSH WA[illegible] SAMPLING DATA SHEET

DATE: [illegible]/21/79 AIR TEMP.(°C): 22

| SITE # | TIME | SALINITY | TEMP. | DIS. $O_2$ | pH | DEPTH |
|---|---|---|---|---|---|---|
| 1 | | | | | | |
| 2 | [illegible] | 28.0 | 31[illegible] | [illegible] | 7.2 | |
| 3 | 11:[illegible] | 31.[illegible] | 12.5 | 11.8 | 7.3 | |
| 4 | 14:50 | 2.0 | 11.7 | 10.9 | 7.7 | |
| 5 | [illegible] | [illegible] | [illegible] | | | |
| 6 | | | | | | |
| 6B | 16:[illegible] | 2[illegible].0 | [illegible] | [illegible] | 7.2 | |
| 7 | [illegible] | 23.0 | 9.4 | 5.8 | 7.1 | |
| 8 | | | | | | |
| 9 | | | | | | |
| 10 | | | | | | |
| 10B | 15:[illegible] | 25.0 | [illegible] | [illegible] | 7.2 | |
| 11 | | | | | | |
| 11B | [illegible] | [illegible] | 10.6 | 13.2 | [illegible] | |
| 12 | [illegible] | [illegible] | | | | |
| 12B | 15:[illegible] | [illegible] | 9.6 | [illegible] | 7.2 | |

DATE: AIR TEMP.(°C):

| SITE # | TIME | SALINITY | TEMP. | DIS. $O_2$ | pH | DEPTH |
|---|---|---|---|---|---|---|
| 1 | | | | | | |
| 2 | | | | | | |
| 3 | | | | | | |
| 4 | | | | | | |
| 5 | | | | | | |
| 6 | | | | | | |
| 6B | | | | | | |
| 7 | | | | | | |
| 8 | | | | | | |
| 9 | | | | | | |
| 10 | | | | | | |
| 10B | | | | | | |
| 11 | | | | | | |
| 11B | | | | | | |
| 12 | | | | | | |
| 12B | | | | | | |

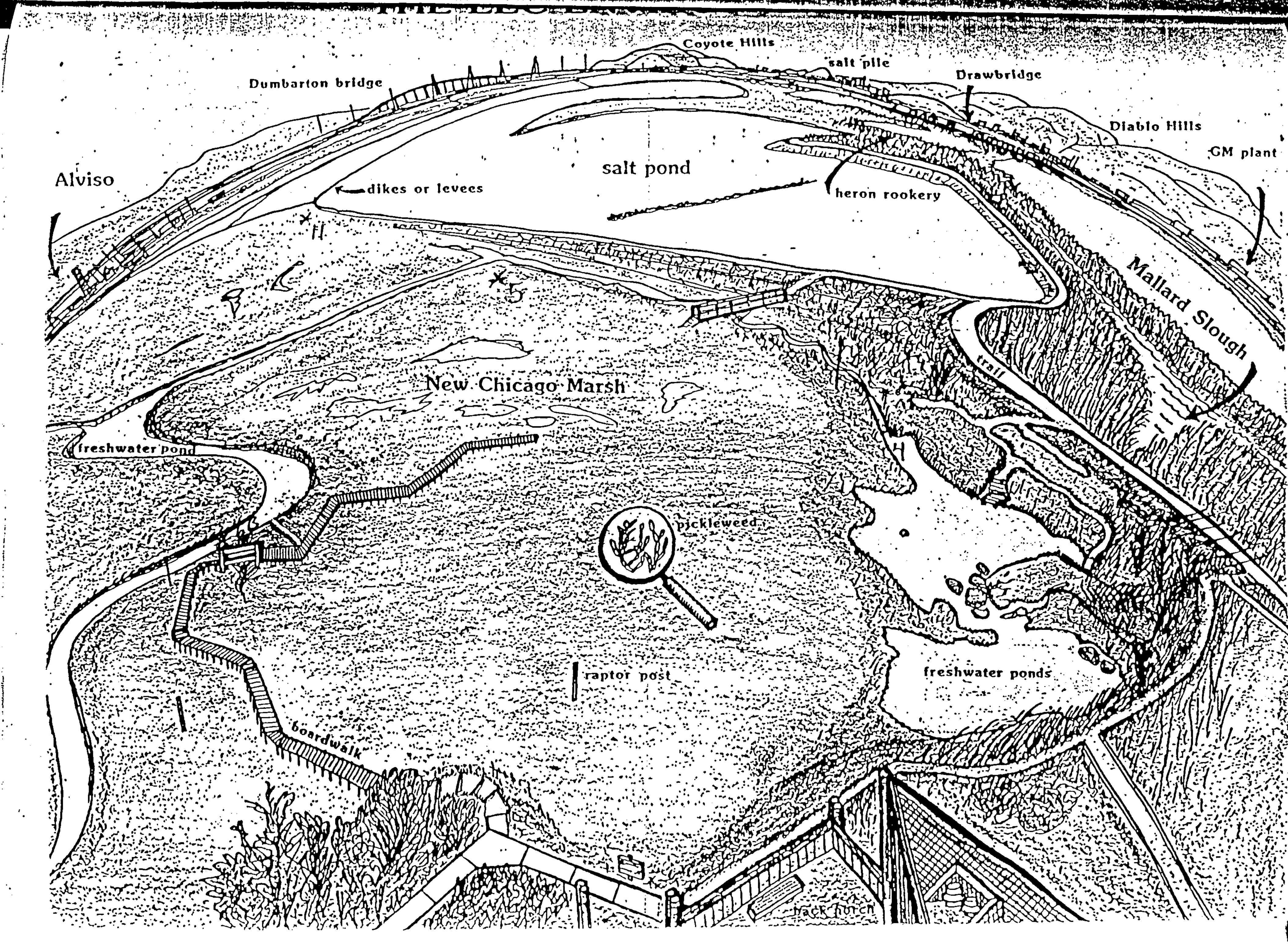
DATE: AIR TEMP. (°C):

| SITE # | TIME | SALINITY | TEMP. | DIS. $O_2$ | pH | DEPTH |
|---|---|---|---|---|---|---|
| 1 | | | | | | |
| 2 | | | | | | |
| 3 | | | | | | |
| 4 | | | | | | |
| 5 | | | | | | |
| 6 | | | | | | |
| 6B | | | | | | |
| 7 | | | | | | |
| 8 | | | | | | |
| 9 | | | | | | |
| 10 | | | | | | |
| 10B | | | | | | |
| 11 | | | | | | |
| 11B | | | | | | |
| 12 | | | | | | |
| 12B | | | | | | |

DATE: 4 16 AIR TEMP. (°C):

4-[illegible] [illegible] pond 62‰

| SITE # | TIME | SALINITY | TEMP. | DIS. $O_2$ | pH | DEPTH |
|---|---|---|---|---|---|---|
| 1 | 15[illegible] | [illegible]‰ | 30°C | 13.0 | 5.2 | |
| 2 | 1[illegible]00 | 0‰ | [illegible]°C | 14.6 | [illegible]7 | |
| 3 | 1[illegible]10 | 19‰ | 27°[illegible] | 15.6 | 5.5 | |
| 4 | 1600 | 2‰ | 30°C | 8.4 | 5.0 | |
| 5 | 1420 | 27‰ | 23°C | 6.8 | 5.7 | |
| 6 | 1635 | 18‰ | 27°C | 14.1 | 7.2 | |
| 6B | | | | | | |
| 7 | 1550 | 0‰ | 28°C | 11.4 | 7.5 | |
| 8 | | | | | | |
| 9 | | | | | | |
| 10 | | | | | | |
| 10B | 1535 | 0‰ | 24 | 8.0 | 7.4 | |
| 11 | | | | | | |
| 11B | 1500 | 24‰ | 24°C | 12.6 | 7.7 | |
| 12 | 1525 | 0‰ | 28°C | [illegible] | 7.7 | |
| 12B | | | | | | |


Coyote Hills
salt pile
Dumbarton bridge
Drawbridge
Diablo Hills
GM plant
Alviso
salt pond
dikes or levees
heron rookery
Mallard Slough
trail
New Chicago Marsh
freshwater pond
pickleweed
raptor post
freshwater ponds
boardwalk
back porch

# * PH READINGS
## (METHODS)

1) paper = 0-14 pH paper sticks

2) meter = SFBBO'S portable pH meter

3) solun. = USED pH indicator solution together with "HACH" chemical KIT

R. L. Ryan
12-19-86

Notes: on New Chicago Marsh Data

1 - between 5/13 and 5/22 the water had receded .6" from shore line at site #1

2 - 5/29 refractometer now being used to find salinity (all dates before: 5/13 and 5/22 used a salinometer) Comparison of 2 methods is shown in #12

3 - 6/5. Site #11 now cut off from main channel due to drying

4 - 6/12 D.O. metered used for site #12 then "went whacky" So may be unreliable data

5 - 6/26 Salinometer readings are also available for this date in original data sheet

6 - Since Site #6 dried up on 6/26 the stake measuring depth was moved to a new site From now on all depth measurements are taken as the <u>amount</u> <u>the</u> <u>water</u> <u>recedes</u> <u>not</u> the total depth as recorded previously

7 - Stake moved again on 10 July.

8 - 7/? new sites 6B and 11B established

9 - 8/7 new sites 10B and 12B established

10 - D.O meter read at 8/21 using 35 ‰ even though salinity may be greater ∴ adjustment must be made

# APPENDIX C

## SUPPLEMENTAL OBSERVATIONS OF SALINITY BY DEBBY J. JOHNSTON

APPENDIX C

## SUPPLEMENTAL OBSERVATIONS BY DEBBY J. JOHNSTON, USFWS

Debby J. Johnston, director of the Environmental Education Center at New Chicago Marsh, made several supplemental observations of salinity in support of this restoration program for this study, as only a few observations of salinity were available for the Triangle Marsh area.

| Station | Date | Time | Measured Salinity |
|---|---|---|---|
| DJ1 | 6/17/87 | approx. 1500 hrs | 5 ppt, on ebb tide after several hours of ebbing |
| DJ1 | 6/22/87 | approx. 1030 hrs. | 29 ppt, just before high tide |
| DJ2 | 6/22/87 | Same | 13 ppt |
| DJ3 (A-16) | 7/2/87 | ---- | 85 ppt |
| DJ3 (A-16) | 7/10/87 | ---- | 82 ppt |

Station Locations:

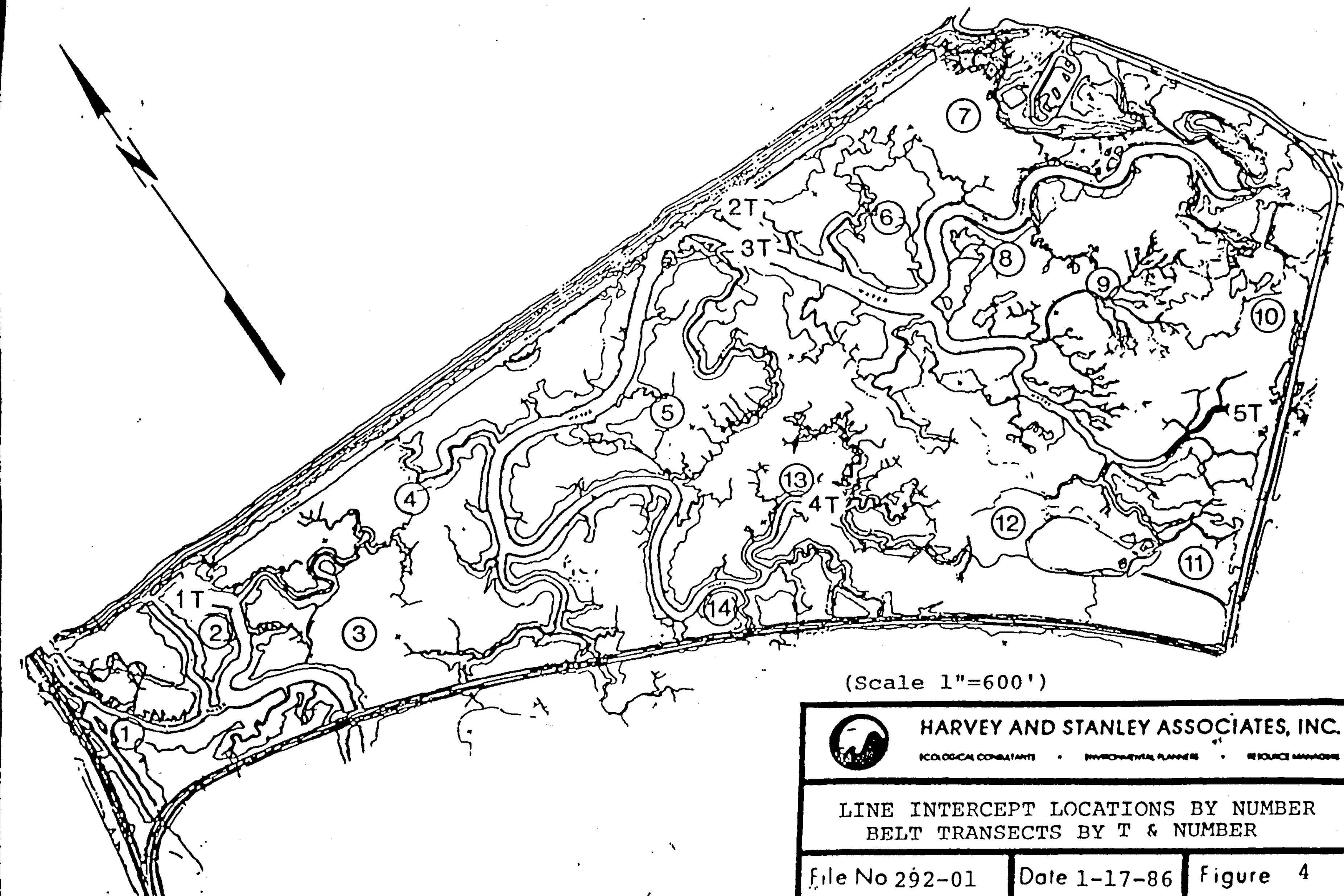
DJ1: Coyote Creek, south bank at railroad bridge

DJ2: Ditch just east of railroad track near Triangle Marsh, immediately south of Coyote Creek

DJ:3: Leslie Salt Pond immediately north of New Chicago Marsh

# APPENDIX D

## MINERAL SOIL TESTS REPORT FROM NELSON LABORATORIES ON SAMPLES FROM NEW CHICAGO MARSH. LOCATIONS OF SAMPLES ARE KEYED TO LINE INTERCEPTS (BY NUMBER) AND BELT TRANSECTS (BY NUMBER AND LETTER T) AS PER FIGURE 4. FROM HARVEY AND STANLEY ASSOCIATES, 1986.




(Scale 1"=600')

HARVEY AND STANLEY ASSOCIATES, INC.
ECOLOGICAL CONSULTANTS • ENVIRONMENTAL PLANNERS • RESOURCE MANAGERS

LINE INTERCEPT LOCATIONS BY NUMBER
BELT TRANSECTS BY T & NUMBER

| File No 292-01 | Date 1-17-86 | Figure 4 |
|---|---|---|

PHONE
931-1266

# REPORT ON MINERAL SOIL TESTS

## NELSON LABORATORIES

3948 BUDWEISER COURT
STOCKTON, CALIFORNIA 95205

REPORT NO. U-22
TS-1867 - 1878

LOCATION NOTES: Harvey & Stanley Associates
Attention: Ms. Nora Monette

DESCRIPTION OF FIELD

Project: New Chicago Marsh

DEPTH OF SAMPLES

DATE RECEIVED 12-17-85

0-8
8-30

ANALYSIS

| FIELD NO. | SAMPLE NO | PH | SATURATION PERCENTAGE | SODIUM MEQ/L SATURATED EXTR | ESTIMATED EXCHANGEABLE SODIUM PERCENTAGE | ELECTRICAL COND MMHOS/CM SATURATED EXTR | SULPHUR REQUIREMENT LBS/ACRE 6" | LIME REQUIREMENT TONS/ACRE 6" | GYPSUM REQUIREMENT TONS/ACRE 6" | NITRATE NITROGEN PPM - SOIL | BICARBONATE PHOSPHOROUS PPM - SOIL | AMMONIUM ACETATE EXTRACTABLE: POTASSIUM PPM - SOIL | AMMONIUM ACETATE EXTRACTABLE: CALCIUM PPM - SOIL | AMMONIUM ACETATE EXTRACTABLE: MAGNESIUM PPM - SOIL | D T P A EXTRACTABLE PPM - SOIL: ZINC | | | | * % Sand | * % Silt | * % Clay | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3B(S) | 5.1 | 92 | 1650 | 52 | 265 | | | | 4 | 20 | 1930 | 1460 | 6510 | | | | | | | | |
| | 3P(F) | 4.3 | 97 | 775 | 41 | 130 | | | | 4 | 37 | 1450 | 1680 | 3790 | | | | | | | | |
| | 6B(S) | 5.1 | 95 | 1350 | 52 | 200 | | | | 10 | 22 | 2030 | 2250 | 6210 | | | | | | | | |
| | 6P(F) | 4.1 | 97 | 615 | 42 | 91 | | | | 4 | 33 | 1320 | 1650 | 3350 | | | | | | | | |
| | 9B | 6.7 | 67 | 620 | 44 | 88 | | | | 5 | 21 | 1300 | 1030 | 2510 | | | | | 0 | 58 | 42 | |
| | 9P | 4.5 | 87 | 570 | 40 | 87 | | | | 4 | 31 | 940 | 1380 | 3040 | | | | | | | | |
| | 12B(S) | 6.1 | 88 | 830 | 46 | 125 | | | | 4 | 20 | 1510 | 2120 | 3570 | | | | | | | | |
| | 12P(F) | 4.2 | 93 | 700 | 43 | 105 | | | | 3 | 31 | 1440 | 1720 | 3530 | | | | | | | | |
| | 15B(S) | 4.1 | 92 | 1070 | 50 | 155 | | | | 2 | 17 | 1530 | 3740 | 5030 | | | | | | | | |
| | 15P(F) | 4.3 | 98 | 470 | 38 | 71 | | | | 2 | 30 | 1070 | 1284 | 2960 | | | | | | | | |
| | 2T-3 | 4.6 | 98 | 390 | 35 | 61 | | | | 4 | 35 | 1020 | 1220 | 690 | | | | | | | | |
| | 5T-3 | 4.6 | 87 | 265 | 29 | 43 | | | | 10 | 39 | 800 | 1310 | 570 | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | |

P.P.M. – PARTS PER MILLION

PHONE
931-1266

# REPORT ON MINERAL SOIL TESTS

## NELSON LABORATORIES

3948 BUDWEISER COURT
STOCKTON, CALIFORNIA 95205

REPORT NO. U-22
TS-1879 - 1885

LOCATION NOTES: Harvey & Stnley Associates
Attention: Ms. Nora Monette

DESCRIPTION OF FIELD

Project: New Chicago Marsh

DEPTH OF SAMPLES

DATE RECEIVED 12-17-85

ANALYSIS

| FIELD NO. | SAMPLE NO | pH | SATURATION PERCENTAGE | SODIUM MEQ/L SATURATED EXTR. | ESTIMATED EXCHANGEABLE SODIUM PERCENTAGE | ELECTRICAL COND MMHOS/CM SATURATED EXTR | SULPHUR REQUIREMENT LBS/ACRE 6" | LIME REQUIREMENT TONS/ACRE 6" | GYPSUM REQUIREMENT TONS/ACRE 6" | NITRATE NITROGEN PPM - SOIL | BICARBONATE PHOSPHOROUS PPM - SOIL | AMMONIUM ACETATE EXTRACTABLE: POTASSIUM PPM - SOIL | CALCIUM PPM - SOIL | MAGNESIUM PPM - SOIL | DTPA EXTRACTABLE PPM - SOIL: ZINC | | | | * % Sand | * % Silt | * % Clay | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 6A | | | | | | | | | | | | | | | | | | 22 | 78 | 0 | |
| | 2T-1(S) | 5.2 | | | | 68 | | | | | | | | | | | | | | | | |
| | 2T-2 | 4.3 | | | | 48 | | | | | | | | | | | | | | | | |
| | 2T-4(F) | 4.7 | | | | 58 | | | | | | | | | | | | | | | | |
| | 5T-1 | 5.7 | | | | 32 | | | | | | | | | | | | | | | | |
| | 5T-2 | 5.1 | | | | 33 | | | | | | | | | | | | | | | | |
| | 5T-4 | 4.2 | | | | 46 | | | | | | | | | | | | | | | | |

*Mechanical analyses done on air-dried, pulverized, screened and mixed samples.

No pre-treatment procedures were made to remove organic matter. soluble salts or carbonates, etc.

P.P.M. - PARTS PER MILLION

# REPORT ON MINERAL SOIL TESTS

PHONE
931-1266

NELSON LABORATORIES
3948 BUDWEISER COURT
STOCKTON, CALIFORNIA 95205

REPORT No U-22
TS-1900

LOCATION NOTES Harvey & Stanley Associates, Inc.
Attention: Ms. Nora Monette

DESCRIPTION OF FIELD
Project: New Chicago Marsh

DEPTH OF SAMPLES

DATE RECEIVED 12-23-85

ANALYSIS

| FIELD NO. | SAMPLE NO | pH | SATURATION PERCENTAGE | SODIUM MEQ/L SATURATED EXTR | ESTIMATED EXCHANGEABLE SODIUM PERCENTAGE | ELECTRICAL COND. MMHOS/CM SATURATED EXTR | SULPHUR REQUIREMENT LBS/ACRE 6" | LIME REQUIREMENT TONS/ACRE 6" | GYPSUM REQUIREMENT TONS/ACRE 6" | NITRATE NITROGEN PPM · SOIL | BICARBONATE PHOSPHOROUS PPM · SOIL | AMMONIUM ACETATE EXTRACTABLE: POTASSIUM PPM · SOIL | AMMONIUM ACETATE EXTRACTABLE: CALCIUM PPM · SOIL | AMMONIUM ACETATE EXTRACTABLE: MAGNESIUM PPM · SOIL | DTPA EXTRACTABLE PPM – SOIL: ZINC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | #10 | 4.6 | 80 | 250 | 29 | 40 | | | | 1 | 41 | 830 | 820 | 1970 | |

P.P.M. – PARTS PER MILLION